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AN INQUIRY INTO THE RELATIVE VALUE OF ALUMINIUM AND ITS ALLOYS TO THE ARTS.

BY H. PEMBERTON, JR.

[*Read at the Stated Meeting of the* FRANKLIN INSTITUTE, *Wednesday, September 19, 1888.*]

JOS. M. WILSON, President, in the chair.

Mr. PEMBERTON: Of late years a considerable amount of attention has been paid to the metal aluminium. Much has been written about it; many plans have been proposed for its extraction, and numberless patents, embodying these plans, taken out, both in the United States and abroad. In fact, the subject appears to possess a species of fascination, as it has attracted attention from all directions. Parties supplying the raw materials or chemicals used in the experiments report that the demand for such comes not only from chemists and metallurgists, but also from business men, lawyers, and professional men of all kinds. The long list of foreign patents on the subject shows how widely it

attracts interest. Prof. Richards' treatise on aluminium contains fifty-four pages—one-sixth of the entire book—on the manufacture of the metal by processes other than the regular one of Deville.

There is no difficulty in giving an explanation of this. Of all the metals, properly so called, the compounds of which make up the crust of the earth, aluminium is the most abundant. This statement is literally true; there is no exception to it. It is evident, therefore, that there can be no difficulty in obtaining material to work upon. Now, taking ordinary clay as an instance, it can be readily shown that in every cubic yard there is at least 800 pounds of aluminium, the lowest recorded price of which is five dollars a pound. Clay can be had, in many cases, at a cost not exceeding that of digging it out. The apparent profit can readily be calculated.

The practical outcome, however, of all of this work, and of all of these experiments, is that the only process by which any quantity worth speaking about, of the pure metal aluminium—in contradistinction to its alloys—has ever been extracted, is the process of Deville, established about a third of a century ago. Modifications in the preparation of the materials have, indeed, been made. But the main features of the process, and the sequence of operations, have remained unchanged. The large aluminium works now just about starting, near Birmingham, England, employ the same chemicals, and rely upon the same reactions that the French chemist did in the fifties.

This company—the Aluminium Company, Limited—has gone into the manufacture on a scale never heretofore approached. According to the descriptions in a number of English technical journals, the works comprise a plant of twenty furnaces for the manufacture of metallic sodium by the Castner process, with a total capacity of about 1,500 pounds a day; a set of twelve regenerative heating furnaces, containing sixty retorts for the manufacture of the double chloride of aluminium and sodium, turning out about 5,000 pounds every twenty-four hours; a Weldon chlorine plant; and furnaces for reducing the aluminium from the double

chloride by means of the sodium. The total capacity of the works is about 500 pounds of aluminium daily. According to a late number of the *Chemical News*, the production of the entire world has heretofore not been over fifty pounds a day. It appears, therefore, that the new company can manufacture in five or six weeks as much as has hitherto been produced in a year. The selling price of the aluminium has been placed at about five dollars a pound as against eleven dollars, lately. The reduction is due partly to the large scale of manufacture, but principally to the cheapening of the cost of the sodium by Mr. Castner's process. It is to be noted that the aluminium made by this company will be in the form of the pure metal unalloyed. If it is desired to produce alloys, they can only be made, or, at any rate, they have only been made by first manufacturing the metal and then alloying it.

Exactly opposite is the case with the Cowles electric smelting process. Here the aluminium has always been produced as an alloy, with either copper or iron. The manufacture of the pure metal on a commercial scale does not appear to have been successful so far, and it is probable that the large demand for the alloys has prevented proper attention being given to this branch of the subject. There is no inherent reason why the metal itself should not be produced, but as a matter of fact, up to this date, such has not been the case.

There is one point, connected with this process, which is worth drawing attention to; that of the reduction of aluminium from its oxide in the presence of carbon, at a high heat. The discovery of this property of the element was as radical and as unexpected as the discovery of a new oxide would have been. All previous efforts to accomplish this had been utterly fruitless, so much so that the hope of so doing had been almost entirely abandoned. Only a few years before the Messrs. Cowles took out their patents, the late Mr. Walter Weldon asserted that it would be about as sensible to try to get five from two times two, as to reduce alumina by carbon. "Never prophesy, unless you know," said Artemus Ward. This property of the metal is worth

drawing attention to, as the practical results of the new process appear to have overshadowed a discovery very interesting from a scientific point of view.

The electro-smelting process appears to have been making great advances, of late. A description of it was embodied in a Report of the Committee of Science and the Arts of the FRANKLIN INSTITUTE (this JOURNAL, July, 1886). Since this report was published, several improvements have been made. It has been found practicable to tap the furnace, and allow the molten metal to flow directly into the ladle or into slabs, instead of letting it cool in the furnace and then putting it cold into crucibles to be remelted. This has practically doubled the capacity of the plant. Another improvement has been in the use of beauxite, as well as corundum, for a raw material, thus ensuring an abundant supply of alumina. The works at Lockport, N. Y., have now two dynamos of 217 electric horse-power each, driven by water-power. The new establishment at Milton, England, has a 402 E. H. P. machine, put up experimentally and to be followed by others. Both of these works are reported to be running day and night.

It appears, then, that the aluminium industry has at length attained a firm footing and is well established. The two lines of manufacture differ essentially in their characteristics. One is a chemical process, the other a metallurgical. One produces the pure metal only, the other only its alloys. One is a complicated process, the other a simple one. Indeed, the Cowles process is extremely simple, consisting, as it does, of only the dynamo, with the power to drive it, and the application of its current to the mixture of carbon, alumina and the metal to be alloyed. Compared with this, the Deville process is a very elaborate one. Compared with any process, it is a very elaborate one. Indeed, it is doubtful if in the whole field of chemistry and metallurgy together there can be found any process which involves such an intricate series of operations as this one does. There is a department for preparing the alumina, a department for preparing the iron and carbon compound (Castner's patent), another for manufacturing the metallic sodium, another for

re-working two-thirds of the sodium remaining as carbonate from imperfect reduction. (This, indeed, is done in an adjacent works, but has to be paid for, of course, just the same.) There is a department for manufacturing chlorine by the Weldon process; another for mixing the alumina, carbon, and salt, moulding and drying the same; another for treating this mixture with chlorine at a red heat for the production of the double chloride of aluminium and sodium, and finally one for treating the double chloride with sodium by which the alumina is reduced to metal. The manufacture of some high-priced organic compound—for instance, Fahlberg's saccharin—may approach this, but it is doubtful if it exceeds it. The Solvay process of manufacturing soda-ash has often been cited as one having had a long uphill fight. But the Solvay process had the additional struggle of having to manufacture its product for less than two cents a pound, or else not at all, whereas metallic aluminium is sold for twice as many dollars a pound. It needs no expert to see that the cost of the aluminium in alloys, as made by the electro-smelting process, must necessarily be only a fraction of that of the metal made by the Deville. It follows, therefore, that the latter process will not be likely ever to compete with the former in the manufacture of alloys, but will have as its legitimate field the production of the pure metal. It is dangerous to assert a negative. But it is hard to see how there can be any escape from the above deduction. Perhaps a possible exception may be named in the case of certain alloys of aluminium and silver—such as *tiers argent* and a few others of like kind, used in table ware.

There are three properties, or characteristics of aluminium, that make it valuable in the arts. It is a light metal (sp. gr. 2·56), being about one-third as heavy as iron. It is a pretty metal, and not very readily acted upon by atmospheric influences. In this respect it rivals silver, which is blackened by sulphuretted hydrogen, by which aluminium is not affected. Upon exposure for some time, however, or by handling, the surface loses its brilliancy and becomes, through oxidation, more or less "dead," resembling tin or zinc, though superior to them, as the color is much whiter.

In the third place, it is a fairly strong metal, about equal to brass. It is destined to play a valuable role in the manufacture of philosophical instruments. Prominent manufacturers state that the weight of theodolites, levels, compasses, sextants, etc., is about one-third less when made of it, and seem to think that there is no doubt of its being largely employed at the quoted English price. All the bearings and wearing surfaces of these instruments must still be made of brass, as aluminium is not hard enough. It is coming into use for making beams of chemical balances with a capacity up to as much as 200 grammes, and has long been used for the smaller weights. The moulds for casting such beams are the same as have been used for the ordinary bronze. Opera- and field-glasses, when made of it, are much lighter and can be used with great ease and comfort. It cannot be employed for cooking utensils, as it dissolves easily in organic acids in the presence of chlorides, such as common salt (Roscoe). A few other uses in which the pure metal appears to advantage, are aluminium leaf, fine wire lace, certain surgical instruments, suture wire, dental plates, etc. Aluminium jewelry has failed to make any headway; it tarnishes too easily and becomes brittle.

It will be observed that nearly all of the above uses are for objects small in size. Many suggestions have been made for its use on the larger scale, as in aërial navigation, or for engineering and constructive purposes. Some of these are of a very sensational nature, as for example:

"The dead weight of trains could be saved by constructing freight and passenger cars of aluminium. * * * Ships larger than the *Great Eastern*, with less draught, could be constructed nearly entirely of aluminium, including the machinery and boilers which at present weigh down vessels seriously. * * * Railway beds, sleepers, ties, rails, bridges, and all, will be cast solidly in their places, with airy aluminium palace cars dancing over them 100 miles an hour or more," etc.

There is a fallacy involved in all such writing, which may be worth showing up. The writer's attention is preeminently attracted by the low specific gravity of the metal.

When employed in any construction where it will be required to withstand severe stress, the metal with which it will immediately come into rivalry will be steel. The specific gravity of steel is almost exactly three times that of aluminium. Of course an inch rod of the latter metal will, therefore, weigh only one-third as much as an inch rod of steel. But when we examine the tensile strength of the two we find that steel has three times the strength of aluminium. It follows, therefore, that to make the aluminium rod of the same strength as the steel, it must be three times the size. The two rods will now weigh exactly the same. Where, then, is the advantage of the low specific gravity of the aluminium?

The extraordinary qualities of many of the aluminium alloys have long been known. The bronze is the strongest of cast metals, and when rolled, the strongest of rolled metals. Nor does it corrode as ordinary bronze does, and its fine golden color gives it a very pleasing appearance. Aluminium brass is noted for its great strength, for its extraordinarily high elastic limit, and for its cheapness. Being composed of equal weights of zinc, copper and ten per cent. aluminium bronze, it contains only three and one-third per cent. of aluminium; hence its lower price.

Aluminium iron is now extensively used in the production of wrought-iron castings (Mitis castings). That the fusing point of wrought iron should be reduced almost 500° by the addition of only one one-thousandth of its weight of aluminium, is another instance of the wonderful properties of this extraordinary metal. The effect of its addition to cast iron is shown in a paper on this subject by W. J. Keep. [This JOURNAL, **126**, p. 220.] Large quantities are now being used also with steel, a very minute amount ensuring the solidity of the castings. Indeed, it appears that aluminium will be used almost universally in the metallurgy of steel and of iron, including puddled iron. Its strength-giving properties are extraordinary. There is hardly any metal with which it will not alloy. And it alloys with nothing that it does not improve. It would be only tedious to attempt to describe its endless applications.

Two of the most important, however, may be noticed. The bronze is destined to play an important part in the manufacture of cannons. The war that is waging between experts, regarding the relative value of cast and of built-up guns, is so fierce, that it appears difficult to obtain a discussion on the subject that does not involve the introduction of this pet fight. Aluminium bronze can, of course, be used for either type, although the cast gun is naturally much the cheaper. Such cannon could be made to possess almost any desired combination of properties, from 114,000 pounds tensile strength and five per cent. elongation, to 90,000 pounds and 10 per cent. and to 72,000 pounds and 47 per cent. The castings would be free from blow holes, could be poured at a comparatively low temperature, would be free from any separation of the ingredients or liquation and would therefore be of uniform composition throughout. The plant required to construct them would be simple compared to the elaborate establishments necessary in the construction of the steel guns of the built-up type. Unlike these latter, the bronze gun, when worn out, could be melted up and cast over again, as the value of the metal in them is about two-thirds that of a new gun. Aluminium bronze stands this treatment on account of the above mentioned freedom from liquation.

Aluminium brass is now being used by the United States Government for the manufacture of propeller blades for the new war vessels. Various metals have been used for this purpose. Cast iron is too weak. Steel has some admirable qualities, but is very liable to corrosion, the average life of a steel blade being only four years. Ordinary bronze has been used, but is deficient in strength. Manganese bronze has, until lately, headed the list. Our Government, therefore, ordered the propellers to be made of this metal. Attention, however, was drawn to aluminium brass, and numerous comparative tests were therefore made, with the following results:*

	Mang. Bronze.	*Al. Brass.*
Tensile strength per square inch, tons, . .	29 — 31	34 — 50
Transverse " " " " cwts., . .	28 — 52	75 — 85
Price per ton in ingots, ...	£112	£103

* See *Engineering*, London, April to June, 1888.

The order for manganese bronze was accordingly countermanded, and aluminium brass adopted in its stead.

It is difficult to speak of these alloys without appearing to be guilty of extravagance; their quality is so uniformly excellent, their appearance so fine, their uses so many. But hundreds and hundreds of tests, similar to those above given, have been made, both officially and in private, and the results obtained have invariably substantiated all that was claimed for them. The chemical process at Birmingham also has a wide future before it. It can hardly be said to have more than started as yet, and the introduction of its "silver from clay" will naturally require time. Much is owing to chemistry for what it has done in the extraction of this elusive metal. But it cannot be denied that the value of aluminium in the arts will be chiefly in its alloys, and that the greater debt of gratitude is due to that protean and subtle form of motion known as electricity.

ALUMINIUM.

By HANFORD HENDERSON, Professor of Chemistry and Physics, Philadelphia Manual Training School.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *Monday, January 9, 1888.*]

Prof. HENDERSON was introduced by Dr. PERSIFOR FRAZER, Professor of Chemistry in the INSTITUTE, and spoke as follows:

LADIES AND GENTLEMEN:

It is my purpose, this evening, to speak to you for a few moments on the subject of aluminium, an element whose name is to-day in almost everybody's mouth. You may have observed that in different mouths it has taken different forms. From some we hear of it as aluminum, while others are always careful to say aluminium. On grounds of both euphony and historic usage the longer name has, I

think, decidedly the preference. The substance of the element, unfortunately, has not attained so common a currency as its name. It has been called, and not without propriety, "the metal of the future." There is a dual significance locked upon in this designation. The metal is so almost noble in its qualities, so useful in its application to the arts, and in all respects so much to be desired, that as we wish all good things for the future, so we wish for it, aluminium. Had it been known in Sir Thomas More's time, it would undoubtedly have been the only metal used by the Utopians. But it is also the metal of the future in another and much less desirable sense. So persistently has it resisted the best skill of our metallurgic art, that it has taken some faith to believe that the metal would not always belong to the future and never to the present. However, ours is a progressive age, and the metallurgy of aluminium, though somewhat sluggish, does advance perceptibly. Our knowledge of the problem is to-day a little greater than it was yesterday. To-morrow, we may reasonably hope, will find our store of still better dimensions. The work of the past few years has been particularly encouraging. In calling your attention to this promising though somewhat elusive metal, therefore, I do so from a belief that the subject is one of growing importance, and will in time merit the share of interest you may bestow upon it.

You are acquainted, I doubt not, with the story of Tantalus. The position of the chemist in quest of aluminium is almost as unfortunate. The metal he seeks is all around him. He can scarcely move without treading on some of its compounds. Yet it eludes his eager pursuit, like some metallurgical will-o'-the-wisp. It recedes from his touch with almost the same persistence as the water and the fruit from the unhappy King of Phrygia.

Iron is the symbol of our present material civilization. It is among the most abundant of metals. It is, indeed, everywhere, for it is the great pigment of nature. It paints our sandstones brown; our bricks, red; and our clays, yellow. You can scarcely get out of the sight of it. But this comparatively new metal, aluminium, is even more abundant.

We do not know of what the centre of our great whirling earth is made. As the globe, taken as a whole, is between five and six times as heavy as water, while the rocks open to our study are only about two and a half to three times as heavy as that standard, we may not unreasonably suppose the core to be composed of the heavier metals, iron, lead, zinc, perhaps silver, gold and platinum. Of the composition of the surface of the earth, however, we have more definite information. Oxygen, the gas upon which life itself depends, makes up about one-half of these rocks; silicon, the basis of ordinary sand, about one-fourth, while aluminium stands third quantitatively in our recognized list of seventy odd elements. You see how relatively abundant this metal is in combination with other elements. And not only is there a great deal of it in absolute quantity, but the forms in which it occurs in nature are also correspondingly numerous.

Mineralogists have described and named nearly a thousand different minerals. In more than two hundred of these, aluminium occurs as an essential constituent. With many of its more beautiful forms you are doubtless familiar. It does not paint with the generous hand of iron, but it is a far more subtle colorist. There is scarcely a gem mineral, outside of the diamond and the rock crystal, that does not contain aluminium. The brilliant sapphire is an oxide of the metal. Of similiar composition are the oriental ruby, the oriental topaz and the commoner form, corundum. Add a little iron to this and we have the valuable abrading material known as emery. The real ruby and the much prized gem, alexandrite, are compound oxides of the metal. Among the silicates it occurs in nearly all the known varieties, from the common clays and other rock-forming aggregates to such royal gems as the emerald, the garnet, the lapis-lazuli, the party-colored tourmalines, and the topaz. As a hydrous phosphate, it gives us the turquois, one of the most beautiful among the mineral blues.

I had in my possession at one time a very interesting ring. The band was made of aluminium, and displayed a fine oriental ruby, thus illustrating to excellent advantage the appearance of both the metal and its oxide.

These treasures, however, constitute a very inconsiderable part of the earth's surface. It is made up, for the most part, of much commoner stuff, and it is with this that the metallurgist has to deal. Of the many forms of mineral compounds in which aluminium occurs, there are but four which are at present made the subject of his skill. These may properly be termed ores of aluminium. They are: corundum, the common oxide, which occurs in some plenty in the mountains of western North Carolina; cryolite, the double fluoride of aluminium and sodium, which is brought to Philadelphia by the shipload from Arksut Fiord, in Greenland; beauxite, the hydrated oxide of aluminium and iron, which occurs abundantly in Southern France, and kaolinite, or common clay, the silicate of the metal, which is found almost everywhere.

In nearly all of the older rocks we find an appreciable amount of gold. In the soils derived from the disintegration of these masses, the same precious metal is to be found. Some one has taken the trouble to calculate that the clay underlying Philadelphia contains at least $15,000,000 worth of gold. But as it would take many times this sum to effect its extraction, the metal is likely to remain where it is. No one, I believe, has had the courage to calculate the value of the aluminium contained in the same clay beds. I shall not tax you with such a calculation, but I will ask your patience with a few figures that I have used for a less extended computation. I believe that they will do more than anything else I can say to impress you with the commercial value of the metal, and the present state of our chemical knowledge concerning its extraction. I am going to ask your attention, not to the vast amount of clay underlying our city, but to a single cubic yard of that material. I give the calculation in detail, believing that some of you who are not familiar with such processes may not find it uninteresting.

A cubic foot of water weighs approximately sixty-two pounds; consequently a cubic yard of that fluid will weigh 1,674 pounds. The specific gravity of clay may be taken at 2·5. The weight of a cubic yard of clay therefore would be

two and a half times the weight of the same volume of water, or 4,185 pounds. There is about forty per cent. oxide of aluminium in ordinary clay and about fifty-six per cent. of metal in the oxide, so that a cubic yard of clay contains about 937 pounds of metallic aluminium. At $12 a pound, an average price, this is worth over $11,000.

This result is rather surprising. Let me repeat it. One cubic yard of ordinarily pure clay contains an amount of aluminium for which society is willing to pay over $11,000.

Nature is full of challenges to our inventive skill, and our powers of observation and reasoning. Not an apple falls to the ground in any quiet country orchard that does not challenge us to find out why it falls. The youngest school-child will tell you very glibly that it is the force of gravitation. But press him a little further, and ask him what is the force of gravitation, and he will be silent. He cannot answer your question. Neither can his masters. We do not know. These every-day, unexplained facts of nature seem to me like so many giant interrogation points constantly staring us in the face.* Even the clay, you tread under foot, is, you see, in an humbler, though more practical way, another of nature's challenges.

Aluminium has indeed been called "Silver from Clay," a name refering to its appearance and origin. But you must not be under the impression that because this clay silver costs about as much as the real silver, no efforts have been made to accomplish its easier extraction. I presume that there is not a single chemist the broad land over who has not, at some time—more probably, perhaps, when he was young—given serious thought to the problem. And to-day, I think I may say without exaggeration, that there are hundreds of earnest workers seeking its practical solution. Nor have their joint results been insignificant. There was a time when the metal in this same cubic yard of clay would have been worth twenty-two, or forty-four or even sixty-six thou-

* Although in these days it requires more courage to declare a thing impossible, than possible, Prof. Helmholtz has recently expressed the opinion that gravitation is incomprehensible, and Mr. Herbert Spencer has long regarded it as belonging to the Unknowable.

sand dollars. There was a time before that when it could have been obtained for no price, however fabulous; and a still earlier time when the very existence of a metal such as this was unsuspected.

To present the outlines of this progressive history, and to familiarize you in some slight degree with the appearance and properties of a metal in whose rising fortune I have so great a confidence, are the full measure of the evening's ambition. So far as I am aware there is absolutely nothing original in what I shall have to say. My "interest" in the metallurgy of aluminium, is the same in kind, as your own. It has no market value.

The great French chemist, Lavoisier, seems to have been the first to suggest the existence of metallic bases in the soils and alkaline earths. Sir Humphrey Davy, of safety-lamp fame, attempted to verify the truth of the suggestion, but though he succeeded in isolating the alkaline metals, sodium and potassium, by means of electricity, he failed to separate aluminium. Oersted, in 1824, came very near to the solution of the problem. Indeed, it is an open question whether he did not isolate the metal, but as his method did not give satisfactory results in the hands of other experimenters, the fame of the discovery of aluminium is generally accorded to Wöhler, who, in 1827, decomposed the chloride of aluminium by means of metallic potassium. Here the matter was permitted to rest until 1845, when the German chemist resumed his investigations, and by allowing the vapor of the chloride to pass over potassium contained in platinum receptacles, obtained globules of the metal of sufficient size to enable him to determine its principal properties. It was, however, less fusible than cast iron, and had the disadvantage of decomposing water at ordinary temperatures, two qualities which gave little promise of the future usefulness of the metal, even should it ever be isolated in sufficient quantities to enter the markets. It has since been found that the infusibility of Wöhler's metal was due to the platinum with which it was alloyed; and the ease with which it decomposed water, to the probable presence of either potassium or the unchanged chloride of aluminium.

And now we come to the epoch of greatest moment in this metallic history. In 1854, the genius of Henri St. Claire Deville was attracted towards the possibilities offered by the new metal. It came about, as we express it, by accident. Deville was experimenting upon the salts of aluminium, and for purposes of the work in hand attempted to prepare the metal according to Wöhler's earlier method. He failed in the original purpose of his experiment, but succeeded in obtaining globules of very pure metallic aluminium, and in determining for the first time its true properties. He was thus led to admire the beauty of a metal with which his name has since been inseparably associated: and to devote his large knowledge to an attempt to make the metal available for human uses. It was Michael Angelo who said: "Genius is infinite patience," and its truth was beautifully illustrated in the case of Deville. He applied himself to his chosen task with uncommon persistence and with uncommon results. He did his work with such thoroughness that only the cheapening of electric energy has enabled us to increase the store of information which he bequeathed to succeeding metallurgists. His first step was to supplant potassium by the cheaper and less dangerous metal sodium. By improvements in the manufacture of this indispensable reagent, he reduced its cost to a mere tithe of what it had formerly been. In the production of the chloride of aluminium he also introduced better processes, and by carrying out Wöhler's reaction, thus modified, on a large scale, Deville placed aluminium on the list of commercial products. During the latter part of his work, he enjoyed the patronage of the Emperor Napoleon III, who was chiefly actuated, it is said, by the hope that the extreme lightness of the metal would make it valuable in naval warfare. At the Paris Exposition of 1855, it was first exhibited in public. A large bar of the metal was shown, bearing the title, already quoted: "Silver from Clay." The first article made of aluminium, of which I find any record, was a baby's rattle, for which the material, on account of its extreme sonorousness, was admirably adapted. It was intended for the Prince Imperial, the poor boy who afterwards lost his life in Zululand.

France has ever remained the home of the aluminium industry. Of recent years, it has also developed to an encouraging extent in England. It has gained but a limited hold among the activities of Germany, Switzerland and the United States.

The methods of preparing metallic aluminium in vogue at the present time do not differ essentially from those of the past. If they have any distinctive feature, it lies in the completeness and perfection with which the various details have been worked out. It is in this humble, though all-conquering way, that the successes of to-day have been achieved. If one were to seek out all the methods, proposed as well as provided, for the isolation of aluminium, the task would be much more difficult than the one I have undertaken. But as our purpose includes only the consideration of those processes by which the market is actually being supplied, I shall sufficiently tax your patience if I ask you to regard the three methods of reduction which now divide the attention of practical metallurgists. These are: (1) Deville's method in its modern form; (2) electric methods, which include both those in which the current is used simply as a source of intense heat, and those in which the selective action of electrolysis is utilized, and (3) that indefinite though promising class of methods, which may be summed up under the general name of projects.

At the present time nearly all the metallic aluminium produced is made according to Deville's method. It is the sole source of the metal in France and in England, and, indeed, it has recently been so greatly improved that unless some exceedingly advantageous method of reduction is proposed, it promises to remain so. The study of the metallurgy of aluminium is therefore largely covered by the study of this one method. There are three distinct operations involved in the process:

(1) The preparation of the double chloride of aluminium and sodium.

(2) The preparation of metallic sodium.

(3) The production of metallic aluminium by the reaction between the double chloride and the sodium.

The manufacture of the two necessary reagents is the most tedious, as well as the most expensive part of the entire process. The effort of inventors has therefore been chiefly directed towards the improvement of these preliminary operations.

At the great French establishment at Salindres, the crude material employed is the mineral beauxite, the hydrated oxide of aluminium and iron. It is finely pulverized and then thoroughly mixed with sodium carbonate. The mixture is strongly calcined in a reverberatory furnace, by which the aluminium is converted into a soluble aluminate of soda, while the iron remains as the insoluble sesqui-oxide. By washing with warm water, the two are easily separated. The aqueous solution of the aluminate is then treated with carbon dioxide gas, which precipitates the aluminium as a hydrated oxide, and regenerates sodium carbonate. A second filtration and washing separates the two. To convert alumina thus prepared into the double chloride of aluminium and sodium, it is mixed with carbon and common salt, chloride of sodium. The mixture is made as homogeneous as possible, and formed into balls as large as a good-sized orange. These are thoroughly dried at a temperature of about 150° C., and are then packed into earthenware retorts, where they are calcined at a red heat. Meanwhile chlorine gas is introduced into the bottom of the retorts. The double chloride of aluminium and sodium is thus formed, and volatilizing, passes over into earthen pots, where it condenses and may be stored away for future use. The simple chloride of aluminium was employed in the early days of the industry, but as it is deliquescent, that is absorbs moisture from the atmosphere, it is difficult to preserve, and has been almost if not entirely superseded by the more convenient double chloride. The formula of this salt is Al_2Cl_6 2NaCl.

A somewhat different method is in use at the English aluminium works at Birmingham. Alum is there employed as the crude material for the production of the double chloride. It is mixed with coal pitch, and calcined at a low temperature. Water is driven off, and sulphur, potash and

alumina remains. After subjecting the residue to the action of steam and air, at a low red heat, it is placed in a vat of hot water. The potash is thus dissolved out, and the insoluble alumina collected and dried. It is then converted into the double chloride by the usual process.

The second operation in Deville's method is the preparation of metallic sodium. As commonly carried out, the operation presents no great difficulties, but it is wasteful and therefore expensive. I give it in some detail, because I want you to fully appreciate the cleverness of an improved method devised by one of our compatriots, which promises to radically change the conditions of the aluminium industry in Europe. The older process, then, consists in reducing sodium carbonate by means of charcoal. As the carbonate is easily fusible, were the two simply heated together, the result would be that the carbon would float on top of the liquid mass, and, consequently, fail to accomplish its work of reduction. It is, therefore, necessary to add about fifteen per cent. of lime, in order that the mixture shall remain infusible and the carbon and soda be kept in contact with each other. The three reagents are mixed as intimately as possible, and subjected to a preliminary calcination at a red heat. This makes the mass more compact, and removes a considerable amount of carbon dioxide. It is afterwards placed in small wrought-iron cylinders and heated to a temperature of perhaps 1,400° C. At this heat the reaction between the soda and charcoal takes place; the alkali is reduced and distils over into suitable condensers. Only about two-fifths of the metal contained in the charge is recovered. The greatest waste, however, is in the labor, the wear and tear of the "plant," and the fuel required to attain so high a heat. All of these causes combined have made sodium an expensive metal. It has been selling in this country for $1.50 a pound, and it has been calculated by a competent English chemist that on the other side of the water it costs four shillings per pound to produce. As it takes something over three pounds of sodium to make one pound of aluminium, it will be seen that this item alone is largely responsible for the high price of the metal. Cheap sodium means comparatively cheap aluminium.

The improved process, to which I have alluded, is that invented by Mr. H. Y. Castner, of New York City. It has not been the result of chance, but of elaborate and systematic experimentation. Mr. Castner, I understand, was attracted to the aluminium problem, while he was yet a student at Columbia College. After an examination into the conditions of its metallurgy, and the possible directions for improvements, he came to the conclusion that the most probable field for better things lay in the cheaper production of sodium, and accordingly he devoted himself to that. I think he worked on the problem for a couple of years. The result of his work has been the production of a process so admirable that the only fault I have to find with it is that I did not invent it myself. Others have felt the same towards the process and from both sides of the Atlantic warm praise has been bestowed upon it and upon its inventor.

The germ of Mr. Castner's improvement is simplicity itself. Instead of making use of an infusible mixture, so that the carbon and sodium compound should be kept in contact, he has obtained the same result by a much more rational device. The little particles of carbon are weighted by means of particles of iron, and so, instead of floating uselessly on the surface of the sodium salt, mix through the whole mass and accomplish their work of reduction under much less wasteful conditions. The improvement you see belongs to the domain of physics and consists of so simple an expedient as increasing the specific gravity of the reducing agent until it equals or somewhat exceeds that of the fused salt. The process is not in use in America at the present time, but has been warmly welcomed in England. Large works are being erected at Birmingham, where both sodium and aluminium will be final products.

Caustic soda is used in preference to the sodium carbonate. The reaction is represented with sufficient accuracy by the following equation:

$$6NaOH + FeC_2 = 2Na_2CO_3 + 6H + 2Na$$

The carbide of iron here symbolized is replaced in

the practical working by a specially prepared mechanical mixture, which is found to act as a perfect equivalent. The so-called "carbide" is prepared by mixing together definite amounts of finely-divided iron and melted pitch. When the mixture cools, it is broken in pieces and coked in suitable retorts. This finely ground metallic coke is the reducing agent which has solved the problem of cheap sodium. The reduction is carried out in capacious cast-iron crucibles. The charge consists of caustic soda of the highest obtainable strength and the proportion of so-called "carbide" needed to satisfy the formula given.

The charged crucibles are placed in a small furnace where they are moderately heated for about thirty minutes. The mass fuses, and for a time boils with considerable violence, owing to the plentiful escape of hydrogen. At the end of the preliminary heating, the fusion becomes quiet and the crucibles are transferred to the distilling furnace. Here each crucible is placed upon a small elevator platform and is raised into position. The covers of the crucibles are stationary, and are made with convex edges. The crucibles themselves have grooved edges in which a little powdered lime is placed. By simply raising them into the furnace they are effectually sealed during the process of distillation, and may readily be detached when that process is completed and a freshly charged crucible is wanted. Tubes project from the stationary covers and lead to the condensers where the distilled sodium again solidifies. The hydrogen escapes from a small opening in the opposite end of the condenser, and is generally lighted in order to show how the distillation progresses. The operation lasts about an hour and a half and is carried out at a temperature of about 825° C. instead of 1,400° as in the older method. The residues consist mainly of carbonate of soda and metallic iron, both of which are again utilized in future distillations, the one in the form of caustic soda, the other in the reducing "carbide." The whole process is extremely simple and ingenious. It will produce metallic sodium at a cost of less than one shilling a pound. The English company, which is now putting the process into commercial

operation promises to place aluminium on the market in a few months at a price not greater than $5 a pound. If this can be done successfully, the uses to which the metal is put will be greatly increased, for it is making its way in certain fields at more than double that price.

I have dwelt upon Mr. Castner's invention with particular pleasure, both because it comes from a thinking rather than a so-called "practical" man, and because it is so neat a solution of a difficulty of somewhat long standing that it should encourage others to attack similar problems in the faith that equally simple solutions are to be found, if one will but look with sufficient persistence.

We have now come to the third operation in Deville's method, the utilization of these expensively won reagents in the final reaction by which metallic aluminium is produced. A difficulty which beset the early metallurgists was the provision of a flux sufficiently light to permit the reduced metal to sink to the bottom of the reducing hearth, and so unite into an available mass. This is now met by the use of cryolite, which serves the purpose to excellent advantage.

The furnace in which the reaction is carried out is a small affair, built after the reverberatory pattern. It is securely bound together by iron tie-rods, for the interior of the furnace during the operation is the scene of pretty severe cannonading. When the double chloride of aluminium and sodium is brought into contact with metallic sodium in the heat, the sodium, by virtue of its greater affinity for chlorine, displaces the aluminium, setting it free in the desired form of a metal, while the chloride of sodium so formed unites with the cryolite and forms a very light and fusible slag. The reduced metal is run off into moulds and at once cast into marketable ingots. A portion of the slag contains enough aluminium in the form of scattered shots of metal to make its re-working profitable.

In these days when the electric methods are promising so freely and so much, it is common to regard Deville's method as rather a thing of the past, but as it has produced, and is still producing, the bulk of all the aluminium in the

markets, I think it not unwise to go on the principle that "a bird in the hand is worth two in the bush," and familiarize oneself with what is actually being accomplished before devoting one's attention to those achievements that are expressible only in the future tense. This is my excuse for having considered at such length an "old-fashioned" but constantly improving method.

In the employment of electricity in the reduction of aluminium there is, at the present time, an atmosphere of hope rather than of realization. Of its ultimate success one can hardly doubt, who has watched its course in other fields. It presents to us a power that furnishes at once an intense heat, or an ability to control chemical action, that is almost irresistible. The Cowles process depends upon the first of these functions, while all electrolytic methods, as their name implies, depend upon the latter.

It is quite within limits, I think, to say that the Cowles process is the most important among all the electric methods. It does not, at the present time, produce pure aluminium, but simply alloys of the metal with copper. These, however, are of such high value that they deserve all of the attention that they are now receiving. The ore used in this process is preferably the corundum obtained from the Southern States. The furnace in which the reduction is carried out is, in its simplest form, a rectangular box of fire-clay, lined with powdered charcoal. The electric terminals are huge arc-light carbons projecting from each end of the furnace. The space between the ends of the terminals is filled with a mixture of ore, granulated copper and coarsely pulverized carbon. When the current passes the resistance offered by the carbon causes so intense a heat that the oxide of aluminium is reduced, and the metal formed unites with the now molten copper. It will be observed that the passage of the current is continuous, and that its only function is to produce a heat far more intense than that obtainable by ordinary processes of combustion. The result of this electric smelting is an alloy containing anywhere from a few per cent. of aluminium up to forty or more. It is cast into ingots, analyzed and re-melted with

sufficient copper to form an aluminium bronze of the desired proportions. The electric furnace has been of late much improved and many refinements introduced into the process. These have made it a commercial as well as a scientific success. As power is the great desideratum, the Cowles Company has located its new works at Lockport, N. Y., where it has available water pressure to the amount of 1200 horse-power. To those who are sensible of the wonderful beauty of the correlation of forces, there is something highly instructive in this quiet transformation of the power stored in a water-fall into mechanical motion, into electricity, into heat, until it finally loses itself in the work of chemical dissociation. I understand that at the present time it costs by this method something less than forty cents per pound to produce the metallic aluminium in the alloys now on the market. They are sold, the company informs me, at the rate of three dollars per pound, with the copper at the market rates. As one of the chief uses of the metal is in the aluminium bronze thus produced, the Messrs. Cowles have solved a very important problem in the metallurgy of aluminium. The process having been so successful in the production of alloys of the metal, it has not unnaturally aroused the hope that it might become a source of the pure metal itself. The function of the copper is to collect and preserve the aluminium as it is reduced. Were it absent, difficulties would arise in the collection of the metal and also from the fact that it would unite with the carbon to form a yellow, crystalline carbide of aluminium, which would require subsequent treatment. It is believed that the copper and aluminium form a true chemical compound, for their union is attended with the disengagement of heat. It is improbable, therefore, that they can be readily separated by any liquation process. There are other metals, however, with which this would be possible. Tin is one of these. When this metal takes the place of copper in the electric smelting, an alloy of tin and aluminium is produced, which, on being subsequently melted with the proper proportions of lead, yields a metallic bath consisting of an alloy of tin and lead beneath and a layer of pure aluminium above. The perfecting of

this process promises an abundance of the pure metal at a very low price. It is not yet carried out on the commercial scale, but I understand is at present the subject of very careful and persistent study. That it may meet with the most ample success, is the wish of all chemical spectators —except those who have rival processes in mind.

Still another modification of the Cowles process has been brought into vogue by the requirements of the Mitis castings in wrought iron. It consists in the substitution of iron for copper, and the consequent production of alloys of aluminium and iron. Only a few years ago the expression "wrought-iron castings" would have been received with incredulity if not ridicule. The high temperature at which wrought iron melts and the difficulty of keeping it sufficiently fluid to cast with any success have limited the working of the material almost entirely to forge processes. Mr. Peter Ostberg, a Swedish engineer, has, however, so far conquered these conditions that the Mitis castings are now to be found in the regular metal market. He has won this victory by means of aluminium. An alloy always melts at a much lower temperature than the average fusing point of its constituent metals. Wrought iron melts approximately at 4,000°F., but if even a fraction of one per cent. of aluminium be added, the needed temperature is reduced by at least 500°. It is on this principle that the Mitis castings are made. To fluid wrought iron, a small amount of metallic aluminium is added, whereby the fusing point is reduced to about 3,500° F. But the temperature of the resultant alloy is little below 4,000°. The thermal difference, or degree of super-heating, permits therefore a leisurely and accurate casting before the metal approaches its point of solidification. The presence of the aluminium is stated to have no disadvantageous effect upon the metal, but rather to increase its tenacity. Although such small quantities are used, the present costliness of aluminium would be a serious disadvantage to the process, but as an alloy of iron and aluminium serves the purpose equally well, the Cowles product is utilized and the two processes become mutually helpful.

In the electrolytic methods, Germany and Switzerland have particularly exercised their ingenuity, although there have not been wanting inventors in the United States who have worked in the same direction. There are any number of methods, distinctive at least in their name, if in nothing else. Sir Humphrey Davy, in the early part of the century, attempted to isolate aluminium by means of electricity, and failed. Both Deville in France and Bunsen in Germany, as early as 1854, electrolyzed the fused double chloride of aluminium and sodium. Since their time the cheapening of the electric current has made the method more practicable. At the present time, however, I know of no aluminium made in this way. The experiments of Dr. Kleiner, of Zurich, have attracted favorable comment and may give rise to an industrial operation. He subjects a bath of fused cryolite to electrolytic action. In Germany the process of Richard Grätzel appears to be the most promising. I have seen beautiful specimens of the metal made by that process, but I am informed by the New York agent of the company operating it, that at present all work is experimental. They hope soon to put their product on the market and will also supply magnesium in commercial quantities.

All of these methods differ from each other, if they differ at all, in the special form of apparatus used, which is supposed to effect a more economical utilization of the current. In principle they are the same, depending simply upon the dissociating action of electricity upon fused compounds of aluminium. The metal collects on the negative electrode. The electrolysis of aqueous solutions of aluminium salts is readily accomplished, but is far too expensive a source of the metal to be industrially available.

Of those various schemes which I have summed up under the name of projects, it is more difficult to speak, for their name is legion. The high prize which awaits the successful inventor of a cheap process for the reduction of aluminium has attracted a class of metallurgical adventurers. They have tried nearly everything that is possible, and have proposed nearly everything that is impossible. The regret which I would otherwise feel in my inability to present all

of these schemes to your attention, is therefore tempered by the consideration that such completeness would not be desirable. It is quite possible that with time some of these propositions will mature into industrial operations. In the absence of any prophetic indications to that effect, however, it will be best to limit our view to one or two processes which have a contemporary interest.

At the present speaking there is but one establishment in the United States where pure aluminium has been a regular commercial product. It is that of Colonel William Frishmuth, at Frankford. It is represented to-night by an admirable display of the metal in the form of ingots, bars, plates and wires. I am unable to state with any definiteness the manner in which the metal has been obtained, for Col. Frishmuth deems it wiser to withhold this information from the public. His older method consisted in a modification of Deville's. Metallic sodium and a volatile salt of aluminium are generated in separate retorts, and brought together while still in the state of vapors, in a third retort, where the reduction takes place, and metallic aluminium is precipitated. He tells me that his present method is a combined smelting and electric one, which promises an excellent and inexpensive product. I am not able to speak of it from personal inspection. This small American establishment has an historic interest from being the place where the aluminium cap of the Washington Monument was cast.

And now it remains for us to consider specifically the advantageous properties which warrant so expensive and so troublesome a metallurgy. I cannot do better perhaps than to refer you to the metal itself for answer. Like all good things, it is its own best advocate. But like them again, its entire merits only appear on very long acquaintance. It will, therefore, be well to enumerate them somewhat systematically.

Physically, then, aluminium possesses properties which distinguish it from all other members of the metallic family. When pure, it has a fine white color, a trifle blue when compared with silver. It is on the whole very pleasing, and

well adapted for ornamental usage. Unlike copper or other base metals, it has neither odor nor taste. It is sufficiently malleable and ductile to be beaten out into very thin foil or drawn into exceedingly fine wire. Of the sturdier properties, aluminium has its full share. It is elastic, exceedingly tenacious, and when hammered, quite as hard as iron. It possesses also a characteristic sonorousness, which leads to the expectation that it may sometime become an advantageous constituent of bell metal.

But the physical property upon which our hope for the future usefulness of aluminium chiefly rests, is its very small specific gravity. It is but 2·56 times as heavy as water. The significance of this levity will appear more strikingly when comparison is made with some of the more common metals. Thus aluminium is only about a third as heavy as iron, less than one-fourth as heavy as silver, and little more than an eighth as heavy as gold. You will have a still more feeling realization of this difference on handling these two slabs of metal which Col. Frishmuth has kindly had cast for me. They possess the same volume, but one is of lead and the other is of aluminium, and one is almost five times as heavy as the other. In considering the costliness of aluminium, its levity must be kept in mind. With both metals at a dollar an ounce, a cubic inch of silver would cost over four times as much as a cubic inch of aluminium.

It would be quite safe to leave to your imagination the manifold advantages possessed by a metal at once so light and so strong. Among the smaller articles which one is called upon from time to time to carry about with him, such as watch, compass, opera-glass, barometer, surveying instruments and the like, the difference between a light and a heavy material is often the difference between comfort and discomfort. The superiority of an aluminium barometer over one of brass weighing about three times as much will not appeal to you very forcibly on casually handling the two, but carry them on successive days over a rough trail, and your opinions will be more pronounced. In more mathematic surveying work, the weight of transit, level or theodolite, is no small tax upon the user. If the consideration be

carried to the more serious problems of portability, the importance of light constructive material looms into still greater prominence. In all of our systems of transportation, by land or water or air, the movement of such large masses of dead weight is an economical evil. The wagon is disproportionately heavy, compared to its burden of freight. A train of vestibuled Pullmans is almost as ponderous when empty as when full. The ocean greyhound carries thousands of tons on each transatlantic passage on which no freight is paid. And so one might follow the entire list of portables and observe the immense advantage that would result from the introduction of a metal as light as porcelain and as strong as steel. We might press the question still further, and speculate upon the greater speed at which so light a train might safely be run, since its diminished momentum would permit it the sooner to be brought to rest.

The metal does not, however, need to be in motion to display the merit of a small specific gravity. In our present structures of iron we have almost reached the limits in the way of possible dimensions. Any further increase in size would be followed by a collapse resulting from the mere weight of the material itself. Could this be reduced two-thirds, and the strength remain unimpaired, one can easily foresee the advantage. There is still another direction in which a small specific gravity means something. This is in the construction of delicate analytical balances. By making the cross-beams of aluminium they are almost perfectly rigid and unalterable, and the centre of gravity of the system is considerably lowered, with a resulting increase of delicacy. Messrs. Troemner & Co., of this city, now construct their finest balances in this fashion, and also employ aluminium for the smaller weights. It may be of interest to know that two such balances form a part of the equipment of the princely laboratory which Mr. Edison has recently erected on the Orange Mountain.

A word should also be said concerning the behavior of aluminium towards heat. At any ordinary temperature, it is absolutely fixed, becoming fluid at about 750° C. It is a

good conductor of heat, and consequently of electricity. It has a larger specific heat than any other of the useful metals; that is to say, it requires a longer time to become either heated or cooled. Deville has suggested that by virtue of this property a plate of aluminium would make a good chafing dish.

In its chemical properties, aluminium is not less remarkable. The most useful of these is its complete indifference to the action of either air or water, and its failure to unite with sulphur under ordinary conditions. A metal which will not rust possesses a manifest superiority over iron and copper or any of the so-called base metals. It was this property which determined the selection of aluminium for the apex of the Washington Monument. As the metallic oxides are poor conductors of electricity, it is important to have a metal for the tips of lightning rods which will not oxidize, and aluminium would be well adapted for the purpose. As a constructive material, a metal which may be freely exposed to the elements without suffering harm needs no praise. As a simple saver of labor it appeals to our philanthropic feelings. When one recalls the multitude of tired arms that daily struggle with the base affinities of brass and try to wring from it an evanescent glitter, the mere thought of a metal which would dispense with this frictional devotion brings a sensation akin to restfulness. In resisting the action of sulphur, aluminium possesses a merit much above silver, which, as you know, blackens on the slightest contact with that element. Spoons and dishes of aluminium are particularly suitable therefore for eggs and other foods containing sulphur. One more mention, and I will close, without however exhausting this catalogue of virtues. In its behavior towards the acids, the metal we are considering shows itself a base of weak affinities. It dissolves very readily in hydrochloric acid, but is almost untouched by nitric and sulphuric. As a substitute for platinum, therefore, in the Grove cell, it has been found to work very well. Towards the weaker acids, such as acetic, it manifests a like indifference, a neutrality which well adapts it for the construction of culinary vessels.

If I have succeeded, by this sketchy statement of the uses of aluminium, in persuading you that the metal is one well adapted to nearly all possible uses, either æsthetic or utilitarian, I have succeeded in making current an opinion which I entertain myself.

I have already spoken, I fear, beyond the proper chronometric limits. Yet I cannot conclude without first anticipating that criticism of incompleteness, which in view of this partial presentation of the subject would be quite justifiable. I am entirely conscious that I have given but a fragment. Into the heights and depths of aluminium, we have scarcely penetrated. In giving this superficial view, however, I have tried to present that side of the cube which most nearly touches the daily affairs of life. By way of caution, I should perhaps add that this view is more favorable than that held by many sober-minded scientists. I do not wish to impose my own enthusiasm upon your better judgment, but for myself, I have great confidence that before many years shall have passed, some chemist will arise among us who shall succeed in transforming by his subtler alchemy, aluminium, the metal of the future, into aluminium, the metal of the present.

NOTE.—The lecturer takes this opportunity of expressing his indebtedness to Messrs. Tiffany & Co.; to Mr. Peter Ostberg; to Col. Wm. Frishmuth; to Messrs. Queen & Co.; to Messrs. Troemner & Co. and others, for their kindness in furnishing specimens of aluminium for exhibition.

TWO REMARKABLE ASTRONOMICAL COINCIDENCES.

By L. d'Auria.

Let s represent the mass of the sun, and c the coefficient of attraction. Then if a body begins to fall toward the sun's centre from a distance D, the acceleration of such body at the end of a fall x will be

$$\varphi \frac{c\,s}{(D-x)^2};$$

and its velocity u can be deduced from the equation

$$\int u\,du = \int \varphi\,dx = cs \int \frac{dx}{(D-x)^2}.$$

Integrating between the limits D and x, and observing that when $x = o$ must be $u = o$, will be found

$$u = \sqrt{\frac{2\,c\,s\,x}{D\,(D-x)}}. \qquad (1)$$

On the supposition of $D = 2\,x$, this formula becomes

$$u = \sqrt{\frac{c\,s}{x}};$$

which is the velocity of a planet revolving around the sun at a mean distance x.

Hence it follows the proposition:

"If a planet be transported to twice its mean distance from the sun's centre and then is let fall toward such centre, it will reach its mean distance again with a velocity toward the sun equal to its mean velocity around the sun."

Let t represent the time a body at a distance D from the sun's centre requires to fall a distance x toward such centre. Will be

$$t = \int \frac{dx}{u},$$

u being the velocity acquired at the end of the fall x. Sub-

stituting for u its value (1), we have

$$t = \int \frac{dx}{\sqrt{\frac{2\,c\,s\,x}{D\,(D-x)}}},$$

which gives

$$t = \sqrt{\frac{D^3}{2\,c\,s}} \left\{ \sqrt{\frac{x}{D} - \frac{x^2}{D^2}} + arc\left(tang = \sqrt{\frac{x}{D-x}}\right) \right\} \qquad (2)$$

On the supposition of $D = x$ this equation is reduced to

$$t = \frac{\pi}{4}\sqrt{\frac{D^3}{2\,c\,s}}. \qquad (3)$$

Now, if the sun's mass were condensed into a point so that it would not be in the way of a body passing through it, then a body falling from the distance D would perform a double oscillation about the sun's centre in a time

$$T = 4\,t = \pi\sqrt{\frac{D^3}{2\,c\,s}}. \qquad (4)$$

On the other hand, if ρ is the mean distance of a planet from the sun, the time such planet requires to perform a complete revolution around the sun will be

$$T_1 = 2\,\pi\sqrt{\frac{\rho^3}{c\,s}}. \qquad (5)$$

Putting $D = 2\,\rho$, equation (4) becomes identical with equation (5); that is, will be $T = T_1$. Hence it follows the proposition:

"A body oscillating about the sun's centre with an amplitude of oscillation equal to twice the mean diameter of the orbit of a planet, will perform a double oscillation in the same time the planet performs a complete revolution around the sun."

The above two propositions are, to say the least, interesting, and exhibit the simplicity of the laws of nature.

THE WRITING TELEGRAPH.

BY MR. W. E. GUMP.

[*Read at the Stated Meeting of the* FRANKLIN INSTITUTE, *Wednesday, September 19, 1888.*]

JOSEPH M. WILSON, President, in the Chair.

Mr. GUMP: There has been no lack of *copying* telegraphs, commonly called autographic, which telegraph a copy of the writing or sketch submitted to them; but telegraphing *fac-simile* letters or characters while forming them with the stylus of the transmitter, so that they are reproduced by a receiving pen, was first made public by Mr. Edward Alfred Cowper, a well-known engineer of Great George Street, Westminster, England. The instruments were publicly exhibited by him at the meeting of the Society of Telegraph Engineers, on Wednesday, February 26, 1879, before one of those overflowing audiences which assemble there only on great occasions.

It has always seemed strange to me that this ingenious apparatus, which constituted the first real autographic telegraph, and at that time took rank with the brilliant series of telegraphic marvels, which from time to time engaged the attention of the world, has never been described in any of the many books on telegraphy which claim to give a history of the art from its conception to the present time. In these books you will find inventions of automatic and so-called autographic telegraphs duly recorded in order, and described in detail, but no mention whatever of the *only invention* which could properly be called *autographic*.

Doubtless it was due to this silence that this system did not sooner receive the attention of inventors, for Mr. Cowper surely pointed the way.

The principle which guided Mr. Cowper to a solution of the problem was that of "compounding the movements of a point in two directions, the one at an angle to the other, the actual movement of the point being the resultant of the two movements."

This principle Mr. Cowper has the honor of *first* applying

to a writing telegraph and, so far, it has proved the *only known* one of writing by telegraph.

Mr. Cowper effected this by employing two separate telegraphic circuits, each with its own wire, battery, sending and receiving apparatus. One of these circuits he made to transmit the up and down component writing of the pen's motion while the other simultaneously transmitted its sidelong component.

Each continuously varying component was transmitted by causing the resistance of the circuit to vary with the component in question.

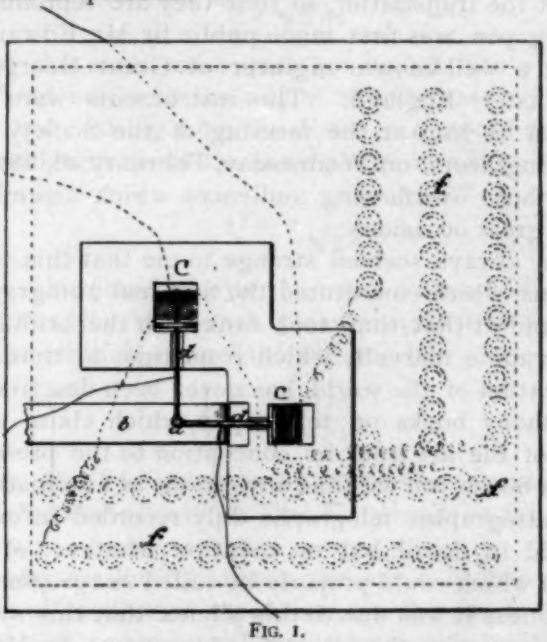


FIG. 1.

The diagrams illustrate the actual apparatus. *Fig. 1* is the plan of the sending instrument and *Fig. 2* an elevation of the same. *a* is the writing style which is held in the writer's hand in the ordinary way, while he shapes the letters one by one on paper pulled uniformly underneath by clock-work.

To *a* are attached two arms, *d d*, one for each circuit. Each arm, *d* (the one insulated from the other), is connected

to its particular battery, the other pole of said battery being connected to earth. Each arm, *d*, is fitted with a sliding contact at its free extremity, and as the stylus, *a*, is

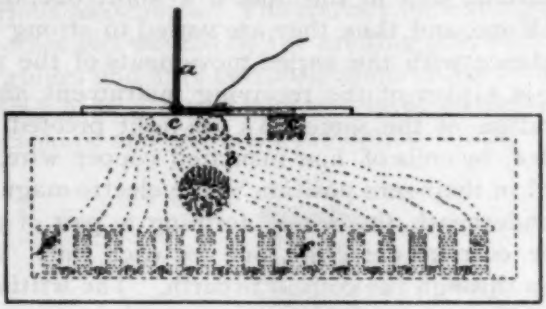


FIG. 2.

moved in writing, these contacts slide lengthwise across the edges of two series of thin metal contact plates, *c c*, insulated from each other.

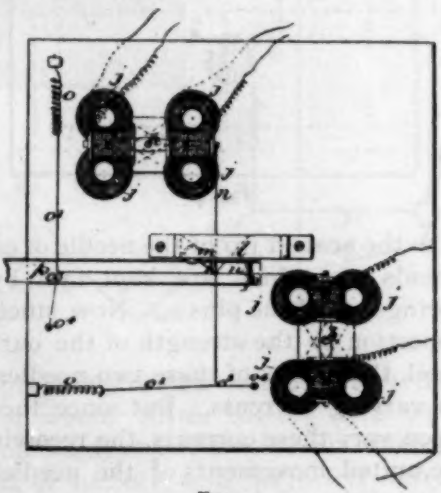


FIG. 3.

Connected between each pair of these plates, there is a resistance coil *f*, and the last of these is connected through the last plate to the line wire. As *d* slides outward across the plates, the current from the battery has to pass through fewer coils, since *d* short circuits a number of coils pro-

portional to its motion, and the fewer of these resistance coils in circuit, the stronger will be the current in the line. If the stylus or pencil makes a large stroke, there will be a strong current sent in the line, if a short one, there will be a weak one, and thus they are varied to strong or weak in accordance with the varied movements of the pencil *a*.

Fig. 3 is a plan of the receiving instrument, and *Fig. 4* the elevation of the same. *h h* are light pivoted needles, surrounded by coils of fine insulated copper wire, *i i*, and controlled in their zero position by the electro-magnets *j j j j*, placed underneath, the whole forming a pair of galvanoscopes or current detectors, one for each line. The line wires pass through the coils *i i* to earth. The writing pen *k*

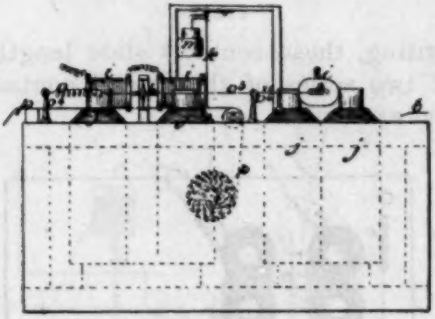


FIG. 4.

is connected to the nearest tip of the needle of each galvanoscope by threads *n n*, which are kept taut by the fibres o_1 o_2 o_3, the springs *o* and the pins o_4. Now, since the needles deflect in proportion to the strength of the current flowing through its coil, the points of these two needles keep moving with the varying currents. But since the motions of the sending pen vary these currents, the receiving pen, controlled by the united movements of the needles, will trace out a close copy of the original writing.

The electro-magnets *j j j j* were magnetized by a local battery. Permanent magnets would have been a gain in simplicity, Mr. Cowper mentions this in his patent. The next improvement Mr. Cowper submitted to the public was in making the movements of the style or pen reproduce

greater or less strength of current by bringing into the circuit a greater or less number of battery cells. By still another method, he effected the variation in the strength of currents by combining various numbers of battery cells with various resistances. The contact bars at right angles to each other and worked by the sending pen, were made to slide in guides and have two projections on their under side, one sliding over a set of contact plates connected to the resistance coils, and the other projection sliding over a set

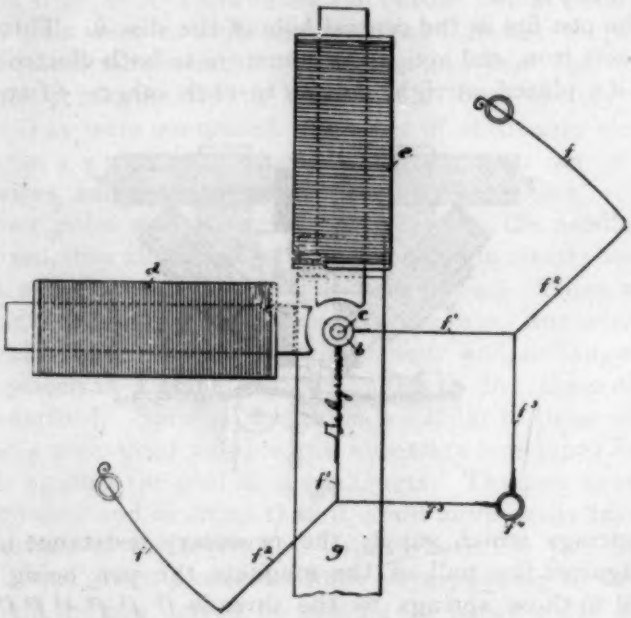


FIG. 5.

of contact plates connected to the battery cells, so that as the operator would write, battery cells were added, and resistance coils left out of the circuit when greater power was wanted, or battery cells were left out and resistance coils taken into the circuit when less power was required.

His receiver was changed to that of a single movable soft iron bar or needle, to which the pen was connected, suspended before two fixed electro-magnets situated at right angles to each other, through the coils of which elec-

tro-magnets, the varying currents of the two circuits were made to pass.

Another plan was by pivoting or suspending the pen itself, and having fixed on it a piece of soft iron exposed to the varying attraction of the electro-magnets in the two directions, acting in opposition to springs, pulling it in opposite directions. The pen used was a siphon pen, the shorter leg of which dipped into an ink reservoir.

The arrangement of the electro-magnets and springs are shown in *Fig. 5*.

The pen fits in the central hole of the disc *b*. This disc is of soft iron, and acts as an armature to both electro-magnets, *d e*, placed at right angles to each other. *f f* are the

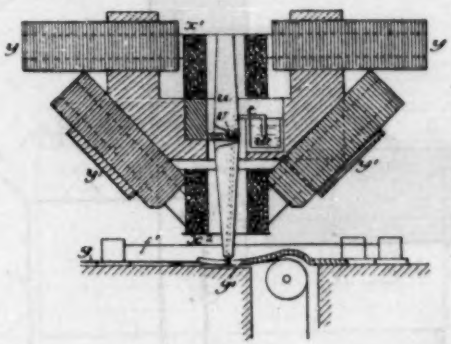


FIG 6.

fine springs which supply the necessary resistance to the pen against the pull of the magnets, the pen being connected to those springs by the threads f^1 f^1 f^2 f^2 f^3 f^3, the last two of which are attached to the post f^4. The paper *g* upon which the message is written by the siphon pen, was moved by clock mechanism.

Mr. Cowper shows various modifications of armatures and pen attachments. Another style of his receivers is shown in *Fig. 6*. You will observe as he progressed that each was less delicate. In this receiver the armature *u* was a bar of soft iron of a tubular section. This armature he called the needle. It held the siphon pen *t*, which had its longer leg passed in through a hole in the

side of the needle, and projected out through another hole at the lower extremity of the same. The shorter leg of the siphon dipped into the ink reservoir *W*. The needle armature was supported by a fixed bracket *V*. This bracket projected into the interior of the needle, and at its extremity supported the needle from a steel point, which was fixed in the axis of the needle. The side of the needle where the bracket entered was cut away, so that the needle when thus supported was free to move in any direction. Stationary coils of wire X^1 X^2 surrounded the needle, one at each end. These coils were of sufficient internal diameter to permit the required movement of the needle, and kept the needle constantly magnetized by means of a local battery with which they were connected. The set of stationary electro-magnets, y y y^1 y^1, were placed in circuit with one of the line wires, and consequently always acted together.

Their poles were so arranged that when the needle was polarized, they all united to deflect it to an inclined position, in the same plane in which they were placed. There was a similar set of magnets connected to the other line wire, and precisely similar in their arrangement and action, which were placed in a plane at right angles to the plane of the set described. Springs and threads similar to those shown in *Fig. 5* were used to give the necessary resistance to the needle against the pull of the magnets. The pen as stated was pivoted and in order that it could more easily traverse the surface of the paper, the paper where the pen moved over it was given a concave form corresponding to the arc in which the pen moved, by passing the paper under a bent form with a hole through it of sufficient size to allow of the largest movements of the pen.

A different device had for its object, the raising of the receiving pen from the paper when the operator ceased to write. This was done by attaching the pen support, by means of a thread, to a spring controlled by an electro-magnet, through the coils of which one of the circuit currents was made to pass. While writing, the thread hung inoperative, but when the currents were caused to cease by raising the sending pen on the completion of the word or

character transmitted, the spring released by the magnet raised the pen out of contact with the paper, thus causing each word to be written separate from the other, as in ordinary writing. There are different ways mentioned by Mr. Cowper for accomplishing this same object. It may interest my hearers to know that among his claims for a patent, Mr. Cowper broadly covers "the combination with a receiving pen of means for lifting the same from the paper when the circuit is broken." The patents of Mr. Cowper also broadly cover the method of writing by means of a varied current. These patents were purchased by the Writing Telegraph Company, of New York.

The writing reproduced on the instruments of Mr. Cowper was of a slightly nervous, tremulous character, but "not sufficiently marked to prevent the handwriting of the person at the transmitting instrument from being readily recognized." The instruments were operated successfully over a ninety mile circuit. They were expensive, could scarcely write twenty words a minute, were delicate in many parts, the contacts were liable to corrode and there were many things to perfect to make it practicable for commercial use.

Mr. J. Hart Robertson next appears in this line of invention. Familiar with many of his experiments and assisted by data furnished by him to the Writing Telegraph Company, I am enabled to state the most prominent of his experiments and devices, which stand as mile posts on the inventive road to a successful writing telegraph instrument. It is but just to Mr. Robertson to state that when he first devised his writing telegraph, he was not aware that Mr. Cowper had ever made any invention of the kind. Mr. Robertson necessarily operated on the same principle of "compounding a point in two directions, the one at an angle to the other," as demonstrated by Mr. Cowper, but the devices for accomplishing the work began far in advance of where Mr. Cowper permitted his experiments to end. Not that his results were obtained at once for, in reality, they were the outcome of experiments, the majority of which were very discouraging. Mr. Robertson's first transmitter

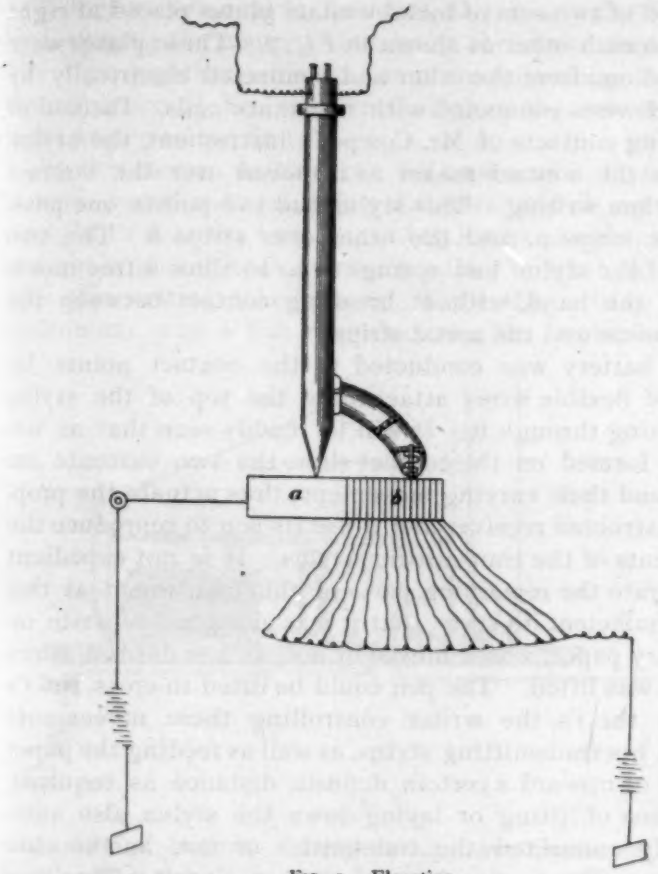


FIG. 7. Elevation.

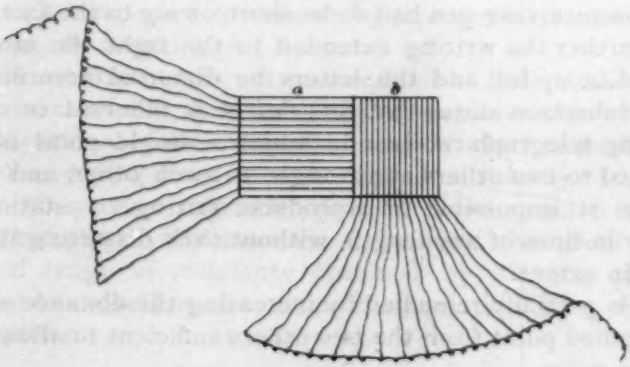


FIG. 7. Plan View of Contacts.

consisted of two sets of metal contact plates placed at right angles to each other as shown in *Fig. 7*. These plates were insulated one from the other and connected electrically by means of wires connected with resistance coils. Instead of the sliding contacts of Mr. Cowper's instrument, the stylus acted as the contact maker as it moved over the contact plates when writing. This stylus had two points, one passing over strips *a*, and the other over strips *b*. The two points of the stylus had springs so as to allow a free movement of the hand, without breaking contact between the stylus points and the metal strips.

The battery was conducted to the contact points by means of flexible wires attached to the top of the stylus and passing through it. It will be readily seen that as letters are formed on the contact slips, the two currents are varied, and their varying movements thus actuate the properly constructed receiver and cause its pen to reproduce the movements of the transmitting stylus. It is not expedient to illustrate the remaining parts of this instrument at this time. Sufficient to state, that it was designed to write on stationary paper, which moved or not, as was desired, when the pen was lifted. The pen could be lifted to cross the t's and dot the i's, the writer controlling these movements through his transmitting stylus, as well as feeding the paper forward or upward a certain definite distance as required. The action of lifting or laying down the stylus, also automatically connected the transmitter or not, as the case might be. The receiver was always in circuit. The lines for the receiving pen had to be short, owing to the fact that the further the writing extended to the right, the more it would be up hill and the letters be distorted accordingly. Mr. Robertson states that this defect is inherent in every writing telegraph receiver in which a single point is fulcrumed to two others at an angle to each other, and thus makes it impossible to reproduce writing on stationary paper in lines of any length, without thus distorting it to a certain extent.

It is partially remedied by increasing the distance of the fulcrumed point from the two others sufficient to allow of a larger radius.

Sometime afterwards, however, he got over the difficulty by fastening the magnet that gave the movement in one direction, together with its complete adjusting device, on the armature of the magnet that gave the movement at right angles to the first.

By this means writing can be produced in lines on stationary paper without being distorted and in an exactly straight line, as the two connecting levers can always move at right angles to each other, no matter in what part of the field the writing takes place. While the writing on this instrument was a fair reproduction, Mr. Robertson was

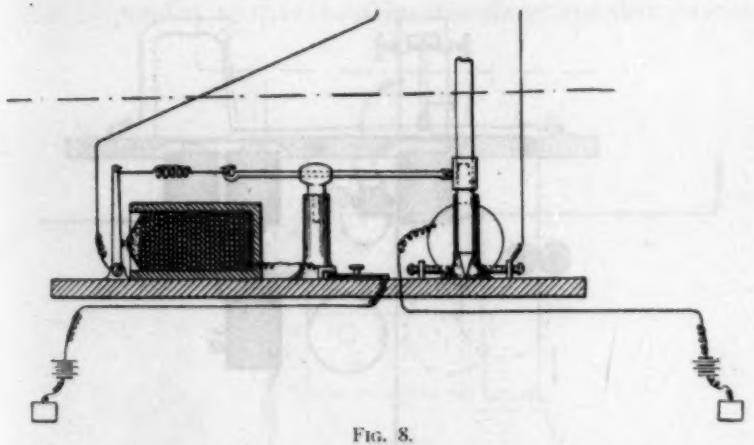


FIG. 8.

not satisfied with its "irregular or wavy character," which he termed "jerky."

This he expected to remove by a proper adjustment of contacts and resistances.

The instrument was not as simple as he wished and Mr. Robertson avoids any complex mechanism. About this time he learned of Mr. Cowper's invention, which caused him to seek a varying movement, more gradual than by "step by step." Care was taken to protect the invention as it had proceeded. His researches showing the great and gradual range of resistance obtained by pressing pieces of carbon together, he soon invented his first carbon transmitter.

This transmitter had forty carbon discs (*Fig. 8*) one-half inch in diameter and one-fortieth of an inch thick in each series, which were placed at right angles to each other. A screw follower was afterwards added on each cylinder which contained the discs, which served to bring the discs in better contact and which allowed the maximum resistance proportional to that of the line to be quickly adjusted. It seems needless to add that the pressure on these series of discs produced by the stylus in writing took the place of the contacts with their resistance coils and gave Mr. Robertson the gradual variation he sought. The first

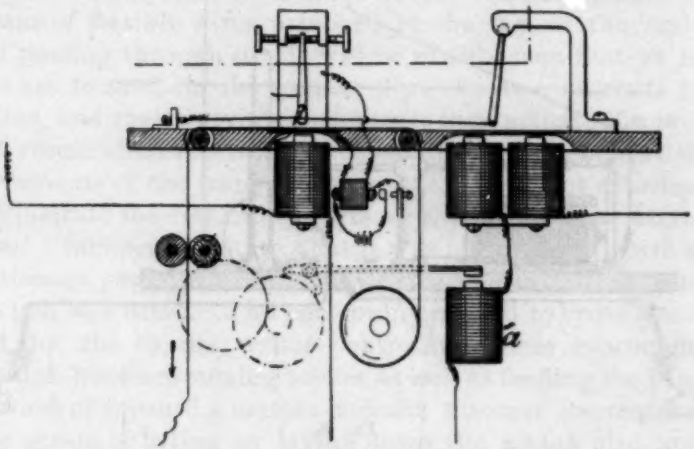


FIG. 9.

receiver constructed by Mr. Robertson to work with this transmitter was constructed as shown in *Fig. 9*. It consisted of two magnets fastened under the base and at an angle to each other. Above each was freely suspended a very light, soft iron armature. One was influenced by what we term the "up and down" and the other by the "right and left" magnet. A pen carrier was pivoted to the former and partook of an "up and down" motion from it. The right and left motion it got from the other armature to which it was connected by a silk fibre.

The armatures were suspended from permanent magnets, which gave enough polarity to them to be repelled by like

poles of the electro-magnets, and attracted by the opposite, the object being to get as large a movement as possible. It was found that the movement was at the expense of power and speed, and the friction on the trunnions working at right angles to each other was objectionable for rapid writing.

The pen was a small tube of aluminium, weighing only two grains. This proved too great a friction on the paper and the idea of a pen and ink reproduction with this receiver was given up for a different plan of writing with it. A light platinum-pointed needle was used for a writing stylus and was suspended so that the point was about one-thirty-second

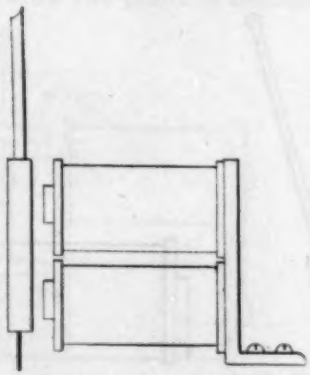


FIG. 10.

of an inch above the paper which moved beneath it. One end of the secondary wire of a local induction coil was connected to this needle and the other end was fastened to a metal plate over which the paper moved. As the needle reproduced the movements of the writing stylus, the induced current from the needle to the contact plate discolored the paper on its passage through it. The magnet *a* was used to control the movement of the paper. The paper was made to start or stop at the option of the writer. The words could be disconnected and the t's crossed by automatically cutting the induction coil out or into the circuit. The paper was a dry chemical paper. It took several weeks of experimenting before one could be ob-

tained which would discolor, without having the stylus in absolute contact with it, or without moistening the paper. The reproduction was excellent, but in the course of a couple of weeks would all fade, and this was considered fatal. The next receiver is shown in *Fig. 10.* It consisted of a piece of soft iron, about three and one-half inches long and one-quarter of an inch square, supported on a steel rod and acting as a combined armature for both sets of magnets, placed at right angles to each other. This was a more powerful receiver.

The weight of the armature being relatively great as compared with that of the fountain pen filled with ink and

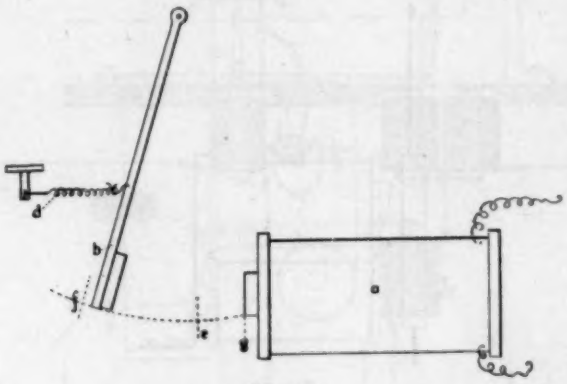


FIG. 11.

pivoted at the upper end of the rod, made the motion of the receiving stylus more easily controlled. Thus one improve ment led to another. On this receiver the reproduction of an "up and down" or "right and left" movement was perfect. The writing, except for its "wavy character," was a good reproduction; but when it came to the full reproduction of an angle between the two movements \, only half of the line could be made. Mr. Robertson attributed this to the "magnetic lines of force," conflicting with and partially neutralizing each other when the armature was in a certain position, and from that sprang his idea of two armatures, magnetically insulated and pivoted on the same rod.

There were yet two defects to be overcome. One Mr.

Robertson termed "eliminating the jumping point of the armature." This is explained in *Fig. 11*. As the strength of a magnet is gradually increased, the armature will also be gradually and evenly attracted until it reaches a certain distance from the magnet, as shown by the letter *e*, when its speed will increase in a much greater ratio than from *f* to *e*. Many expedients were tried to overcome this and utilize the space between *e* and *g*, but it was only by detracting from some other feature. The other defect alluded to, was the tremulous "wavy character" of the writing. He sought to overcome both difficulties by constructing his armature, as shown in *Fig. 12*, to pull downward as well as toward the poles of the magnet. Although

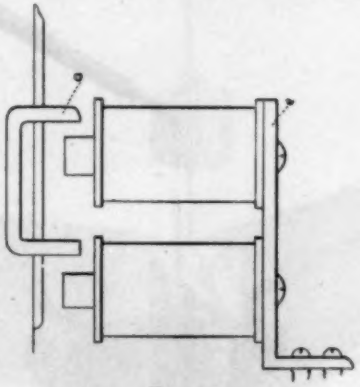


FIG. 12.

there was power lost by this downward pull it was more than compensated for by the steadier action gained. There was still a trembling of the receiver rod at the slightest jar or vibration, and if the operator did not have a very steady hand, the writing would show it very decidedly. A very simple but very important improvement removed this final defect. This improvement was simply immersing the armature or its extension in a vessel containing a liquid.

The first trial made was with the single armature, which moved in a cup of mercury, and although the amplitude of the movement of the armature was small, owing to the large body of mercury used, the improvement was so apparent that experiments were continued.

The result was the adoption of a light inverted thimble, made of German-silver and attached to the armature rod in such manner that it could float in a cup of glycerine. This removed every vestige of the tremor in the writing and made every mark clear and distinct. With the advent of the liquid cup, the fact was demonstrated that almost any kind of armature gave good results, in combination with it, and that if it had been used at the start a great deal of time spent in experimenting would have been saved.

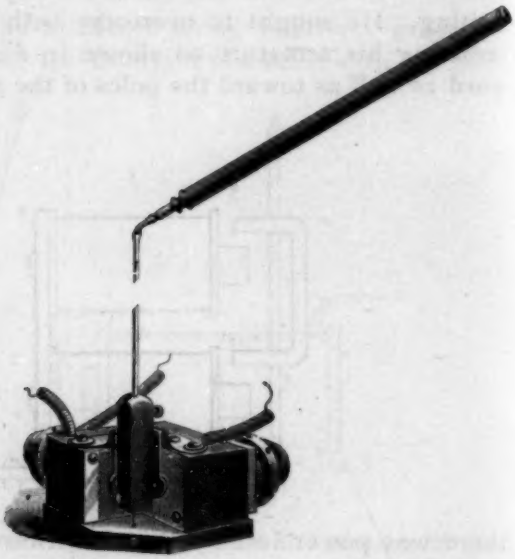


FIG. 13.

From this point progress was more rapid, and we now have instruments which reproduce the writing so accurately, that the paper containing the original must be marked to distinguish it from the reproduction.

The present transmitter (*Fig. 13*) consists of two series of thin carbon discs about one-half inch in diameter, placed at right angles to each other, in a hard rubber receptacle. The normal pressure of each series of discs is adjusted by a screw. The stylus rod has insulated pressure points opposite the piles of discs, and is supported at the base on

thin wire, so that by taking hold of the handle it can be manipulated, as in writing, and in so doing the pressure points are pressed against springs which press upon the carbon discs, and thus vary the current.

Each of these series of carbon discs is in circuit with one of the line wires which are led to the receiver.

The present receiver (*Fig. 14*) consists of two pairs of electro-magnets, each in circuit with one of the line wires and placed at right angles to each other. The rod which

FIG. 14.

carries the pen and the armature has a spring wire projection at its base, and is fastened at a point where the poles would meet if extended. The armatures for each pair of magnets have a brass connection and are placed above the cores of the magnets.

The armature rod carries the inverted thimble, which floats in the glycerine, and also extends above the top of the case and carries the fountain pen.

The armatures respond to the attraction of the electro-magnets, as they are actuated by the varied currents sent

into the lines while writing, and cause the receiving pen to reproduce each letter as fast as made at the transmitter.

The transmitter and receiver are placed in a case about 14 inches long, 9 inches wide, and 8 inches deep. This case (*Fig. 15*) also contains a bell and the mechanism which moves the strip of paper. Above the box appears the handle of the transmitting stylus and the armature rod carrying the pen.

The switch shown on the left for changing the current from the transmitter to the receiver has been dispensed with, and this work is done automatically.

Mr. Robertson also made transmitters which varied the current while writing by immersing electrodes more or less in liquid. Fine carbon spirals, specially prepared by him, were also tried and gave fair results. A comparatively small carbon spiral will give all the resistance necessary; a carbon spiral of five convolutions, about one and two-thirds inches in diameter, gave a minimum resistance of four and one-half ohms when pressed together in writing, and 145 ohms when the convolutions were not in contact. The carbon was $\frac{1}{8}$ of an inch wide and $\frac{1}{87}$ of an inch thick.

Our company had a great deal of trouble in obtaining uniform carbon. Whether sawed from carbon rods and then rubbed down, or moulded in discs and then finished, there was a great variation in their resistance.

Carbon discs, one-half inch in diameter and ·05 of an inch in thickness, after carefully smoothing off each surface and placing some thirty of them in a superficial contact under a pressure of fifteen pounds, would give a total resistance of hundreds of ohms and every lot would greatly vary.

Under these conditions sufficient difference of resistance could not be obtained to operate all instruments alike.

Mr. Harry Etheridge, a young electrician of great promise, was given the problem to solve, and instructed to make each transmitter uniform. Each carbon disc was taken separately, subjected to a constant pressure and its resistance obtained. The pressure was applied superficially and equalled about eight pounds. Under this pressure some discs would show ·1 ohm, another ·6 ohm, another 2·, another 15· ohms, and so

on, many reaching the extraordinary amount of 800 ohms. From this data it was readily seen why thirty discs, taken

FIG. 15.

at random and arranged in series, varied so much in resistance. With care and experience in preparing carbons, they are now all made of low resistance, the majority less than

·2 of an ohm, and none are used above that resistance. In this way our transmitters at Pittsburgh are adjusted to a minimum resistance of five ohms and a maximum of 150 ohms.

Guided by these measurements of resistances in carbons and their resistance as the stylus rod is pressed against them in every movement of about one-twentieth of an inch or less, Mr. Etheridge became convinced that he could construct a transmitter without carbon, which would always prove constant. Several made by him proved failures, but perseverance and the benefit of experience at last succeeded. The Etheridge transmitter bids fair to earn a prominent rank among writing telegraph transmitters. The stylus is arranged to press against a series of steel tongues arranged in a vertical position, and to each of which is connected a suitable resistance. The upper ends of these tongues are tipped with platinum and as they are compressed and expanded, the resistances are thus "cut in" or "cut out," respectively. The resistances are composed of German-silver wire. It is a combination of the Robertson and Cowper systems and does perfect work.

It is due Mr. Etheridge to state that it is by his improvement to our exchange instruments, that we are enabled to record a message on any subscriber's instrument, whether that subscriber is present or not.

The writing telegraph is yet in its infancy, and we all have much to learn about it.

While our company has not confined itself to only one style of instrument, it considers the instrument it has perfected to be the most simple and practical for commercial use.

The field for a writing telegraph is a large one, and its many uses are so apparent it is not necessary to repeat them here.

At our experimental exchange at Pittsburgh we have had the instruments in constant operation throughout the year. Through the winter's storms and the summer's heat the instrument has demonstrated its commercial practicability. A locomotive puffs with heavily loaded freight trains past our exchange, but fortunately the pen writes indifferent to

any noise. We use poles in conjunction with the Electric Light Company, immaterial as to whether our wires are above, below, or surrounded by theirs. The pen writes just the same in utter ignorance of the word induction.

For six months we have had instruments in daily use in several cities, reporting base ball scores by innings. This has been so satisfactory that we are arranging to greatly enlarge the field for the coming year.

We are past the experimental stage: are ready for, and are doing, a practical commercial business, and our company anticipates a bright future for the writing telegraph.

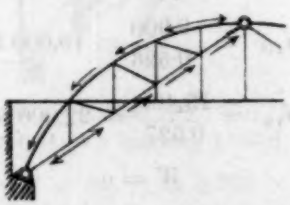
GENERAL THEORY OF JOINTED BOW GIRDERS.

By E. A. Werner, C.E.

(*Concluded from Vol. cxxvi, page 63.*)

STRAINS T OF THE UPPER CORD.

The course of the ties corresponding to the maximal and minimal loadings, is as follows:



hence the numeric maximal and minimal values of T.

MAXIMA.

$$T_1 = \frac{139{,}600}{0{\cdot}537} = 261{,}000 \text{ lbs.} \quad T_2 = \frac{172{,}900}{0{\cdot}759} = 228{,}000 \text{ lbs.}$$

$$T_3 = \frac{198{,}800}{0{\cdot}885} = 225{,}000 \text{ lbs.} \quad T_4 = \frac{219{,}800}{0{\cdot}960} = 230{,}000 \text{ lbs.}$$

$$T_5 = \frac{219{,}800}{0{\cdot}995} = 222{,}000 \text{ lbs.}$$

MINIMA.

$$T_1 = \frac{39{,}800}{0{\cdot}537} = 72{,}000\ lbs. \qquad T_2 = \frac{49{,}400}{0{\cdot}759} = 64{,}000\ lbs.$$

$$T_3 = \frac{56{,}800}{0{\cdot}885} = 63{,}000\ lbs. \qquad T_4 = \frac{62{,}800}{0{\cdot}960} = 62{,}000\ lbs.$$

$$T_5 = \frac{62{,}800}{0{\cdot}995} = 62{,}000\ lbs.$$

STRAINS N OF THE TIES.

We have:

$$W = N \cos \alpha,$$

thus

$$Maxima = N'$$

$$N_{II} = \frac{48{,}400}{0{\cdot}973} = 50{,}000\ lbs.$$

$$N_{III} = \frac{43{,}300}{0{\cdot}919} = 48{,}000\ lbs.$$

$$N_{IV} = \frac{40{,}300}{0{\cdot}961} = 42{,}000\ lbs.$$

$$Minima = N''$$

$$N_{II} = \frac{5{,}700}{0{\cdot}494} = 12{,}000\ lbs.$$

$$N_{III} = \frac{9{,}900}{0{\cdot}526} = 19{,}000\ lbs.$$

$$N_{IV} = \frac{13{,}400}{0{\cdot}627} = 22{,}000\ lbs.$$

$$W = o$$

The general equations of W show, that only *two* members are to be considered, of which the first one always is negative, the second one positive.

It follows thus easily:

W_{II} The only position of the loads producing a negative W_{II} is a loading from 1 — 1. It corresponds to a relative maximum of U, as W_{III} is positive at the same time.

W_{III} The only position of the loads creating a negative W_{III} is 1 — 2, involving a positive W_{II} at the same time.

W_{IV} The only position of the loads making W_{IV} negative and W_{III} positive at the same time is 1 — 3.

W_{IV} becomes furthermore negative for a loading 1 — 2, but W_{III} is then *not* positive.

STRAINS OF THE POSTS.

P_1

The *lower* chord has to be taken into consideration.

W' acting.

As long as W_{II}' is acting the lower end of P_1 which is into consideration, will have no tie, thus:

$$P_1 = o$$

W'' acting.

We know from $W = o$, that the only position of the loads giving W_{II}'' corresponds to a loading 1 — 1. It is thus:

$$P_1 = W_{II}'' (tng\ a_{II}'' + tng\ \gamma) = 5{,}700 \times 1{\cdot}093 = 6.200\ lbs.$$

W = o acting.

This case is included in W'' and W'''.

P_2 LOWER PART.

The *lower* chord is to be taken into consideration.

W' acting.

It is:

$$P_2 = W_{II}'\ tng\ a_{II}' + [U_2 - U_1]\ tng\ \gamma = W_{II}'\ (tng\ a_{II}' + tng\ \gamma)$$

Hence P_2 is a maxima with W_{II}' and the numeric value will be:

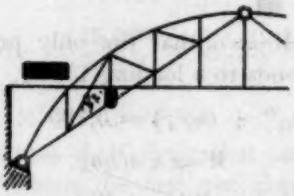
$$P_2 = 48{,}500 \times 0.9026 = 43{,}800 \text{ } lbs. \text{ } (compression.)$$

W'' acting.

We know, that the only position of the loads giving W_{III}'' corresponds to a loading 1 — 2. W_{II}' is then positive at the same time and it will thus be:

$$P_2 = U_2 (tng\ \mu_{III} - tng\ \mu_{II}) + g = -41{,}200 + 63{,}000 =$$
$$= 21{,}800 \text{ } lbs. \text{ } (compression.)$$

$W = o$ acting.



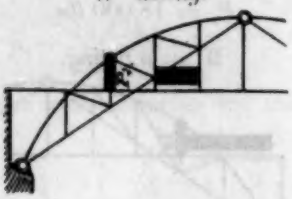
To have the lower end of P_2 free of the action of ties, W_{II}'' and W_{III}' must act. This corresponds to a loading 1 — 1 and the numeric value is then:

$$P_2 = o$$

P_2 UPPER PART.

The *upper* chord is to be taken into consideration.

W' acting.



There is:

$$P_2 = W_{III}' \; tng \; a_{III}' + U_2 \; tng \; \mu_{III} - U_2 \; tng \; \mu_{II}$$

or:

$$U \; tng \; \mu_{III} = 0{\cdot}01470 \; G_1 g_1 + G_2 (1{\cdot}6536 - 0{\cdot}02204 \; g_2)$$

$$U_2 \; tng \; \mu_{II} = \begin{array}{r} 0{\cdot}03136 \; G_1 g_1 + G_2 (1{\cdot}5677 - 0{\cdot}02090 \; g_2) \\ - \; 0{\cdot}01666 \; G_1 g_1 + G_2 (0{\cdot}0859 - 0{\cdot}00114 \; g_2) \end{array}$$

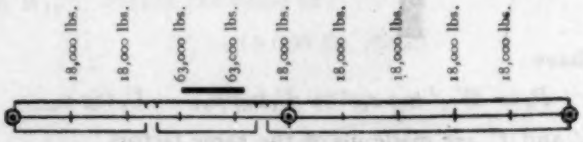
$$W_{III}' \; tng \; a_{III}' = - \; 0{\cdot}00364 \; G_1 g_1 + G_2 (0{\cdot}5659 - 0{\cdot}00754 \; g_2)$$

$$P_2 = - \; 0{\cdot}02030 \; G_1 g_1 + G_2 (0{\cdot}6518 - 0{\cdot}00868 \; g_2)$$

from this follows the maximum line of G_2

$$p_2 = \frac{65{,}180}{868} = 75{\cdot}1 \; \ldots \ldots \; ft.$$

and with it, the position of the loads creating the maximum of P_2:



and the numeric value:

$$P_2 = - \; 0{\cdot}0203 \times 810{,}000 + 126{,}000 \times 0{\cdot}1961 = 8{,}300 \; lbs.$$

(compression.)

W'' acting.

The only position of the loads producing W_{II}'' is 1 — 1, with a positive W_{III}' at the same time.

Hence:

$$P_2 = 18{,}000 \text{ lbs.}$$

$W = o$ *acting.*

The only position of the loads giving W_{III}'' is 1 — 2, with a positive W_{II} at the same time.

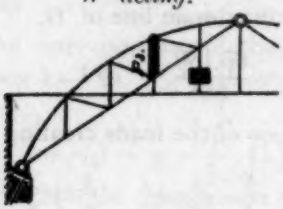
Hence:

$$P_2 = U_2 (tng\ \mu_{III} - tng\ \mu_{II}) = -41{,}200 \text{ lbs. } (tension.)$$

P_3

The *upper* chord is to be taken into consideration.

W'' *acting.*



We have:

$$P_3 = W_{IV}'\ tng\ a_{IV}' + U_4\ tng\ \mu_{IV} - U_3\ tng\ \mu_{III},$$

or, as U_3 and U_4 are made up of the same factors:

$$P_3 = W_{IV}'\ tng\ a_{IV}' + U_4\ tng\ \mu_{IV} + U_3\ tng\ \mu_{IV} - U_3\ tng\ \mu_{IV} - U_3\ tng\ \mu_{III} = P_3 = W_{IV}'\ tng\ a_{IV}' + (U_4 - U_3)\ tng\ \mu_{IV} + U_3 (tng\ \mu_{IV} - tng\ \mu_{III}) = W_{IV}' (tng\ a_{IV}' + tng\ \mu_{IV}) - U_3 (tng\ \mu_{III} - tng\ \mu_{IV})$$

$$W_{IV}' (tng\ a_{IV}' + tng\ \mu_{IV}) = -0{\cdot}00275\ G_1 g_1 + G_2 (2{\cdot}1894 - 0{\cdot}0219\ g_2)$$

$$U_3 (tng\ \mu_{III} - tng\ \mu_{IV}) = +0{\cdot}00659\ G_1 g_1 + G_2 (0{\cdot}7416 - 0{\cdot}00989\ g_2)$$

$$P_2 = -0{\cdot}00934\ G_1 g_1 + G_2 (1{\cdot}4478 - 0{\cdot}01930\ g_2)$$

From it follows the maximum line of G_2,

$$p_3 = \frac{14{,}478}{193} = 75{\cdot}1 \ldots . ft.$$

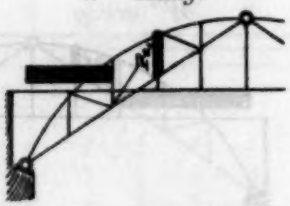
and the position of the loads inducing the maximal value of P_3,

from which we derive the numeric value:

$$P_3 = -1{,}620{,}000 \times 0{\cdot}0934 + 63{,}000 \times 0{\cdot}2898 = 3{,}100 \text{ } lbs.$$

(*compression.*)

W″ acting.



The only position of the loads inducing W_{III}'' is 1 — 2, with positive W_{IV}'. Hence the value of

$$P_3 = 18{,}000 \text{ } lbs. \text{ (tens.)}$$

W = o acting.

The position of the loads inducing a W_{IV}'' and a W_{III}' is a loading from 1 — 3. The numeric value of P_3 is then:

$$P_3 = U_3 (tng\ \mu_{IV} - tng\ \mu_{III}) = 170{,}300 \times 0{\cdot}2346 = 40{,}000 \text{ } lbs.$$

(*tension.*)

P_4

The *upper* chord is to be taken into consideration.

W' acting.

There is, as $N_V = o$;

$$P_4 = U_4 (tng\ \mu_{IV} - tng\ \mu_V)$$

Hence P_4 is a maximum with U_4 or for full loaded girder and the numeric value will be:

$$P_4 = 219{,}800 \times 0{\cdot}196 = 43{,}100\ lbs.\ (tension.)$$

W'' acting.

The *two* positions of the loads inducing W_{IV}'' are 1–2 and 1–3. In both cases, the numeric value of P_4 will be:

$$P_4 = 18{,}000\ lbs.\ (tension.)$$

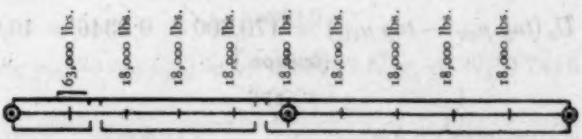
$$W = o\ acting.$$

This case is included in W' and W'''.

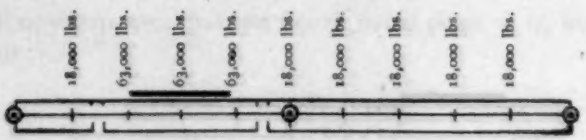
With this it is now possible to compute the absolute maximal and minimal values of P.

We have:

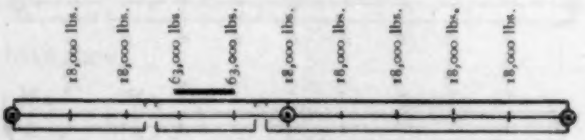
MAXIMA.



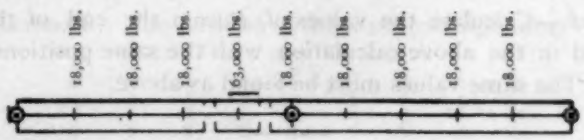
$P_1 = 6{,}200\ lbs.\ compression.$



P_2 *lower part* = 43,800 *lbs. compression.*



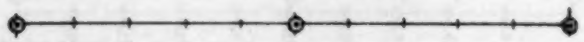
P_2 *upper part* = 8,300 *lbs. compression.*

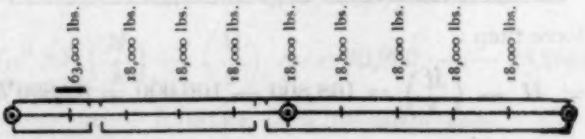
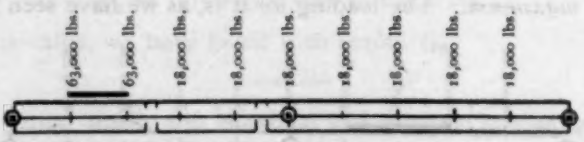


P_3 = 3,100 *lbs. compression.*

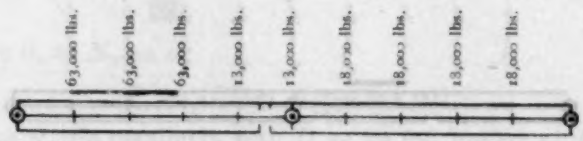
P_4 = 43,100 *lbs. tension.*

MINIMA.



P_1 = *o.*

P_2 *lower part* = *o.*

P_2 *upper part* = 41,200 *tension.*

$P_3 = 40{,}000$ *tension.*



$P_4 = 18{,}000$ *tension.*

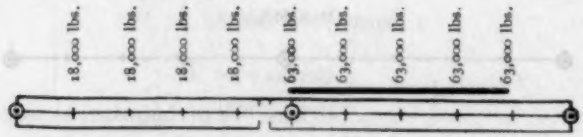
Check.—Calculate the values of P from the end of the post not used in the above calculation, with the same positions of the loads. The same values must be found as above.

As U, W, P, have only two members in G_1 and G_2, these stresses are independent of the loading of the part corresponding to G_2.

I will illustrate this with one example for each stress:

U_4 *min.* is generated when the grider is completely empty.

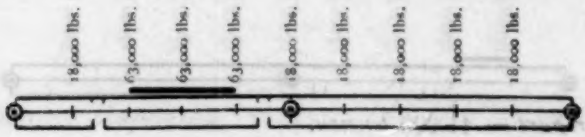
I will suppose now, that the half bow corresponding to G_3, be also loaded, thus:

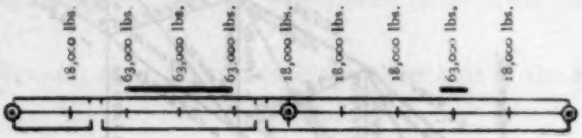


We have then:

$$U_4 = H - \left(\frac{M}{h}\right)_4 = 168{,}800 - 106{,}000 = 62{,}800 \text{ lbs.}$$

The same value, which we have found, with an empty grider.

W_{II} *maximum.* The loading for it is, as we have seen:

I will now suppose, that the fourth panel point of G_3 be loaded also, thus:



We have then:

$$W_{II} = \left(\frac{M}{h}\right)_2 - \left(\frac{M}{h}\right)_1 = +\ 7{,}300 - (-\ 42{,}100) = +\ 48{,}400\ lbs.$$

the same value found with empty right half bow.

P_1 *maximum.* The position of the loads corresponding to it, is:

I will now suppose, that the top joint be loaded in addition, thus:

We have then:

$$P_1 = W_{II}''\ (tng\ a_{II}'' + tng\ \gamma)$$ and it is:

$$W_{II}'' = \left(\frac{M}{h}\right)_2 - \left(\frac{M}{h}\right)_1 = -33{,}900 - (-\ 28{,}200) =$$

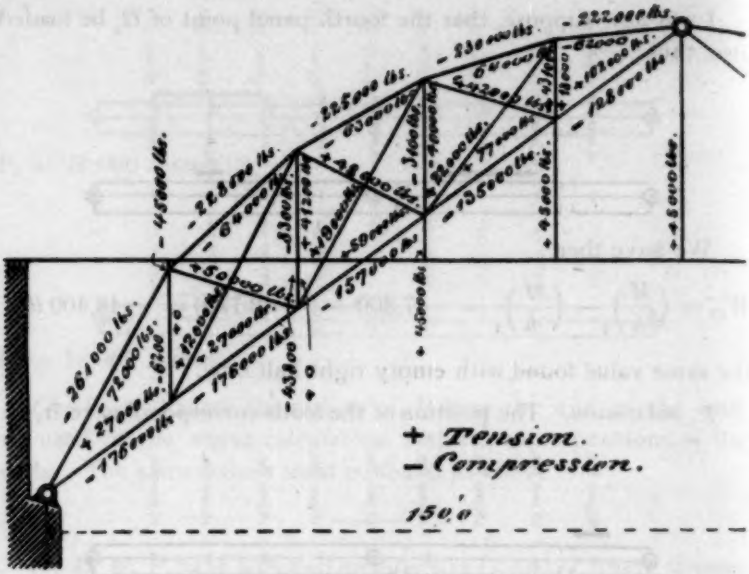
$$= -\ 5{,}700\ lbs. = 5{,}700\ \textit{compression}.$$

hence:

$$P_1 = 5{,}700 \times 1{,}093 = 6{,}200\ lbs.$$

the same value, we have found with empty G_3.

Computing finally the maximal and minimal strains obtained in the previous calculations, we have the following strain sheet:



TRENTON, N. J., *April, 1887.*

ERRATA.

NOTE.—Correct in Part I, of this paper, the following errors:

Page 391, line 7 from top, *read*—

$$V_m = Q - G_1 \text{ instead of } V_m = Q - g_1$$

Page 394, *read* equation 12—

$$\frac{2fx + ly}{2fl} = \frac{\zeta + y}{2f} \text{ instead of } b = \frac{2fx + ly}{2fl} = \frac{\zeta + y}{2f}$$

Page 396, line 13 from top, *read*—

$$\zeta \gtrless y \text{ instead of } \zeta \lessgtr y$$

Page 393, line 3 from bottom, *read*—

$A\ D$, instead of $A\ C$.

Page 405, line 10 from bottom, *read*—

Fig. 18, instead of *Fig. 19*.

In *Figs. 8, 10, 12, 14, 16*, the abscissa g_m is omitted in the lower part of the figures.

In *Fig. 9*, g_{m1}, g_{m2}, g_{m3}, g_{m4}, is omitted in the upper part of the figure.

In *Figs. 18, 19*, g_s is omitted in the lower part of the figure.

In Part II, correct:

Page 491, line 16 from bottom, *read*—

$\Sigma(Y)$, instead of $\Sigma(H)$

Page 493, line 13 from bottom, *read*—

$T_m \cos\beta_m = \tau_m \cos\beta_m + H$, instead of $T_m = \tau_m \pm H$.

Page 494, line 5 from top, *read*—

$$T_m \cos\beta_m = \mp \left(\frac{M}{h}\right)_m \pm H, \text{ instead of } T_m = \mp \left(\frac{M}{h}\right)_m \pm H.$$

Page 55, lines 17 and 18 from bottom, *read*—

"lines of the loads," instead of "lines of the forces."

Page 56, line 15 from bottom, *read*—

$$W_m = N_m \sin\alpha_m = V_m, \text{ instead of } W_m = \frac{h_m}{\Delta x_m} = N_m \sin\alpha_m = V_m.$$

Page 60, line 8 from top, *read*—

$$W_m = \frac{M_m - M_{m-1}}{h_m} = S_m \cdot \frac{\Delta x_m}{h_m}, \text{ instead of}$$

$$W_m = \frac{M_m - M_{m-1}}{h_m} = \Delta S_m \cdot \frac{\Delta x_m}{h_m}.$$

Page 236, line 8 from bottom, *read*—

$\left(\frac{M}{h}\right)_3 = 0{\cdot}01805 + (3{\cdot}15568 - 0{\cdot}0527) - 0{\cdot}01$, instead of

$\left(\frac{M}{h}\right)_3 = 0{\cdot}01805 + (0{\cdot}15568 - 0{\cdot}0527) - 0{\cdot}01$

THE PROTECTION OF BUILDINGS AGAINST WATER OVERFLOWS BY THE MEANS OF ELECTRICITY.

BY LEOPOLD WEIL.

(*Read at the Stated Meeting held Wednesday, May 16, 1888.*)

JOS. M. WILSON, President, in the chair.

Mr. WEIL: This subject was forcibly brought to my notice, some years ago, by having been subjected to two rather uncomfortable and expensive overflows of water, at my place of business.

We are protected against fire and theft, but there is no safeguard against water overflows, and the disquietude, caused by this fact, stimulated me in endeavoring to find means whereby I could protect myself, more especially as a loss of this nature would fall entirely upon me.

The damage caused by water overflows is a very serious matter, particularly in large cities, frequently causing a loss of many thousand dollars, and involving business houses in expensive litigation.

I have, therefore, devised a system which provides an efficient and reliable safeguard against damage to merchandise and other property from overflows of water in buildings, generally resulting from the bursting of pipes, stoppage of drains, or negligence, and sometimes from other causes.

The same consists of a method or system of automatically detecting an overflow, or leakage of water, in a building, which comprises means for directing such an overflow or leakage to an electric water-detecting device, which is normally inactive, but which becomes operative in the presence of water, to sound an alarm and shut off the water supply at the point of overflow or leakage, or to the building.

The water-detecting device, which I call a hydrostat, can be inserted in the floor, basin, tub or tank, according to the kind of protection required.

Horizontal pipes are incased in a wooden box, made to slant slightly, so that a leakage cannot escape, but will be led to the hydrostat.

In protecting a floor, the plumbing is confined within an area limited in extent by a line of one-half inch cleats nailed on the floor, from wall to wall, describing a circle or the shape required; within this enclosure a series of conveying grooves lead to a strainer inserted in the floor and on which is fastened a hydrostat.

The electric devices, by means of which, in case of an overflow, the hydrostat is made to shut off the water supply and sound an alarm, consist of a battery, alarm bell and a trip apparatus.

The first hydrostat I constructed consisted of two sets of conductors running at angles to each other and separated by a material which would act as an insulator when dry and become a conductor when wet. This was inserted in an aperture in the ceiling, directly under another aperture in the floor; the latter was supplied with a strainer and was situated at the base of a series of converging grooves, so as to catch any water which might overflow from the basin or other fixture. I found this apparatus entirely too sensitive, as a single drop of water was sufficient to shut off the entire water supply to the building, and furthermore the insulator became deliquescent from the moisture in the atmosphere, so I was compelled to abandon it.

I have different forms of hydrostats for various purposes; the one that I have here consists of a small vessel, provided with a suitable cap; there are openings to permit the ingress of water and exit of air; I place in the vessel a float, which rises when water enters, until it comes into contact with the conductor and forces its free end, which is connected with one binding post, against, and into contact with, the other binding post in the cap, thus closing the circuit and operating the system.

The trip apparatus consists of an electro-magnet; and an armature with a catch, which, in its normal position, engages with a lever. Upon this lever is suspended a weight, sufficiently heavy to operate the valve to which it is connected.

For the purpose of testing the system, I place in the circuit a test button; by pushing this button, the water ought to be turned off, and in order to denote this, I make a *break in the bell circuit*, which closes only after the valve has operated, thereby ringing this *bell*, which cannot ring unless the water has actually been shut off.

Now you have the system complete; you will imagine this hydrostat inserted in a basin or bath tub, as the case may be; I will first push the button to see if everything is all right. Now I will proceed to pour water into this vessel, and when it reaches the proper height, you will see, it operates the valve and precludes the possibility of an overflow by shutting off the water supply.

We can protect a basin, bath tub, tank, the pipes, the floor, or anything else as may be needed. A basin or bath tub provided with a hydrostat, can be made proof against sewer gas by dispensing entirely with the overflow holes. This is of great importance in many modern houses, where the plumbing adjoins the sleeping apartments.

When employed in hotels, the hydrostat is connected with the ordinary call bell circuit, and in this way the office will immediately be notified, and the room in which the leakage would have occurred be located and overflow prevented. In business houses the greatest danger exists at the time when the occupants have left the premises. This could be guarded against by shutting off the water when locking up, and it ought to be done every night, because unless there are people in the building there is certainly no use for any water. It is, however, frequently neglected through carelessness or forgetfulness, and *all* of the lawsuits which I have heard of in New York for damages from water overflows come under this category.

In order to provide an automatic method for turning off the water at night, I have provided a box into which must be placed the keys to the premises. I prefer to use the keys because they must be used in locking up at the time when no water is wanted in the building. The operation is, viz:

When the keys are removed from the lever, it closes the main circuit, and operates the valve.

The lever of the valve, when the water has been shut off, falls upon a spring which closes the alarm bell circuit; both circuits are now closed; the one having operated the valve to turn off the water and the other giving audible proof that this has been done. The bell continues to ring until the door to the box is closed. The valve cannot be kept open until the keys have been put back into the box, thus leaving the apparatus in condition to operate the valve to shut the supply pipe when the key is taken at night to close the building.

The apparatus can always be tested to ascertain if all the parts are in adjustment and good condition by opening the door of the box and removing the key. Thus in the morning when the box is opened to put the key in its place, the alarm will be sounded if the apparatus is in working order.

In closing, I merely wish to add, that a large insurance company is in operation in Frankfort, Germany, with a capital of 1,000,000 marks, and their business is to insure against damages caused by overflows of water in buildings; with the system I have described, no such precautionary measure is essential, but the very fact that in the old world, water damage insurance companies exist, demonstrates the necessity for some kind of protection in this respect, and I hope the time is not far distant when the term "Modern Improvements," as applied to buildings, will include a system for the prevention of water overflows.

REPORTS OF THE COMMITTEE ON SCIENCE AND THE ARTS.

LANCE'S METHOD OF UTILIZING OIL-CLOTH WASTE.

[No. 1387.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 1, 1888.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination

WILLIAM L. LANCE'S METHOD OF UTILIZING OIL-CLOTH WASTE,

Report: That the object of the invention is to utilize the clippings or waste due to the trimming of sheets of oil-cloth. These trimmings are the unfinished margins of the cloth which are removed by the manufacturer prior to placing the finished material on the market.

Two results were placed before your Committee. One, the result obtained by removal of the applied substance necessary to form the cloth; the other, a carpet, the filling or weft of which was composed entirely of these trimmings.

The first process not being considered by the inventor to possess any real practical value was, therefore, not seriously considered by your Committee.

The second process was represented by a fabric (carpet) having a cotton warp with an oil-cloth filling. The latter is produced by cutting the oil-cloth waste into strips, joining the ends by means of a metallic loop, thus making a continuous strip, which is subsequently twisted so as to throw the painted side outward; these twisted threads, after having been wound into a cop for insertion into the shuttle, are introduced into the fabric in the ordinary manner of manufacture.

The fabric thus produced is very similar in appearance to the ordinary rag carpet, but as the material is not so pliable, the cloth is not so soft nor so compact as its familiar

counterpart. Whether it possesses the elements of desirability, sufficient to win its way as a commercial article, your Committee cannot determine. The process is certainly a novel one and the results obtained are so well defined that it would seem the fabric must eventually find its place in the ordinary household economy, its cheapness and durability being factors that count largely in its favor.

Its cleanliness is undeniable, as the nature of the material is to sift dust rather than retain it.

As before stated, your Committee are unable to properly judge of the practical results likely to follow this invention, but they are quite unanimous in their approval of the effort thus made by Mr. Lance to not only further diversify our manufacturing interests, but to give commercial value to that which has hitherto been valueless and everywhere recognized as a waste material.

All of which is respectfully submitted.

T. C. SEARCH, WM. MCDEVITT,
LOUIS H. SPELLIER, H. W. SPANGLER.

Amended by the award of a Certificate of Merit.

Adopted April 4, 1888.

GEORGE A. KOENIG, *Chairman.*

THE DOUGHERTY RAILROAD SIGNAL.

[No. 1391.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 19, 1887.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination

THE DOUGHERTY RAILROAD SIGNAL SYSTEM,

Report: That the object and aim of the device is that a passing train shall automatically set signals and combinations for the guidance and control of trains following, in such a manner, that while the train setting the signal is notified

at the same time by a suitable alarm that the signal is properly displayed, it cannot alter the position of the same.

The signal being set, devices are provided connecting with the building occupied by a train operator, who alone can return the signal to its normal position. Should the office be vacant or operator off his guard, an alarm is given, and a corresponding signal displayed in the office, which will so remain until the operator has returned to his duty and has received notification that the train setting the signal has passed out of block. Thus following trains are brought to a halt until the signal is changed by the operator, allowing another train to pass.

The object is commendable and gives security from accidents. Any device that has the automatically-setting feature absolutely, and depending on an operator to change the signal back to normal position, is worthy of notice and theoretically seems perfect.

Your Committee do not deem it necessary to go through all the minute details of the signalling system presented, but take the initial or operating box that starts the machinery in motion as the real point of consideration. The device is constructed and operated as follows:

A box is provided, located alongside the rail and fastened to the ties with an opening in the top, through which a lug projects, that is secured to a semi-elliptic spring with elongated slots, the spring being secured to the bottom of box by bolts. The elongated slots allow the spring to expand freely. The lug projects upward and on the inner side of the rail, so that the flanges of wheels will strike and depress the spring, causing a downward movement, depressing a lever which is connected to the main lever, the latter being provided with a ball and tram-way. When the lever is in normal position, the ball or weight is located at or near the centre of motion. As soon as the lever is disengaged, the ball by gravity will roll along the tram-way out from the centre of motion, causing the lever to be depressed by the weight of the ball. The connections to operate the signals are at the opposite end of the lever. The lever with ball cannot be set, or returned, or set to normal position, without

the aid of the operator, connection being made with a building at any distance required for convenient signalling.

Your Committee are of the opinion that the device is mechanically practicable and effective and fully able to accomplish the object desired, and, although not seeing the device in practical use, believe the principle to be good, and worthy of commendation.

Therefore, your Committee would suggest that the device be tried practically on some road to develop the mechanical working of the same.

For further information as to details, the patent papers and illustrated pamphlet of the inventor are appended hereto.

RUFUS HILL, W. BARNET LEVAN,
LUTHER L. CHENEY, C. CHABOT,
CHAS. E. RONALDSON.

Adopted April 25, 1888.

GEORGE A. KOENIG, *Chairman.*

SCIENTIFIC NOTES AND COMMENTS.

MECHANICS.

A VIBRATING ENGINE.—There is being built in Portland, Me., an engine which is the invention of Mr. Lidback, which has quite a number of novel features. I have called it a vibrating engine to distinguish it from a rotary, as the driving apparatus turns through part of a circle. The piston consists of a hollow cylinder, having four wings on its outer side. The outer edge of these wings carry packing pieces, which bear against the inner surface of the steam cylinder proper. Between the wings rectangular plates extend inwardly from the steam cylinder, which are made to bear against the outside of the cylindrical part of the piston. Each wing of the piston is therefore between two of these plates, and moves backward and forward as the piston vibrates. *Fig. 1* will give a fair idea of the arrangement of the parts. *A A* is the piston carrying the wings *B B B B*, each of which is packed by the rectangular piece *C* against the interior of the cylinder *D*. *E E E E* are the plates fitting into recesses in the cylinder *D*, and set up by set screws, two of which are shown at *F F*. *H* is the valve chamber, and steam is admitted through the centre of the piston. Ports are cut through the piston *A*, at *G G*. Two ports, one for steam and one for exhaust, are in each corner, but one lies at one end and one at the other of the piston *A*. The valve used is represented in *Fig. 2*. It consists of a cone-shaped piece of cast iron, *H*, having steam

ports, *I*, and exhaust ports, *K*, cut in it. Steam is admitted through the pipe *L*, and passes through *I*, into the opening in the piston and into the cylinder. The exhaust is taken through the port *K*, into the exhaust pipe. With larger

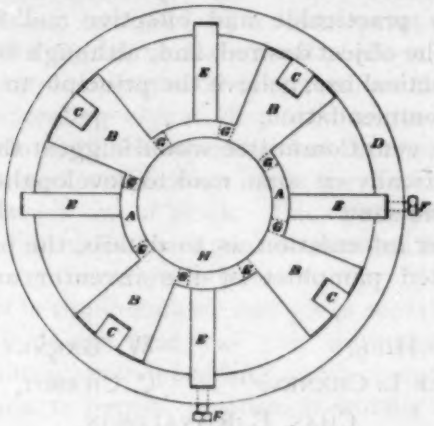


FIG. 1.

sizes separate valves are used, and do away with heating the exhaust from the live steam. The spindle supporting the piston passes through a long

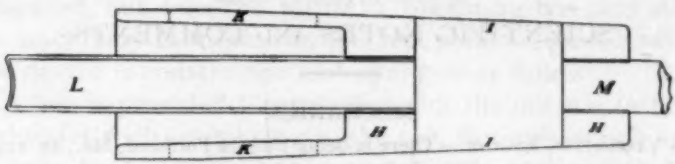


FIG. 2.

bearing, and carries on its end an arm to which the connecting rod is attached. The fly-wheel shaft is carried in the same casting, and is directly over the

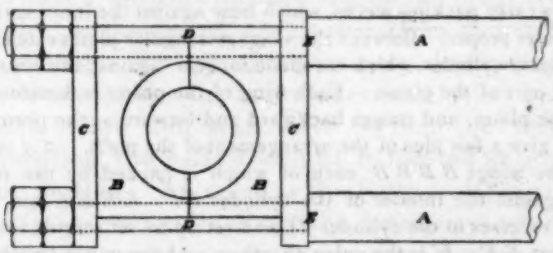


FIG. 3.

cylinder. It is driven directly by the connecting rod, and carries on it what is practically an eccentric for moving the valve. On the smaller sizes a throttling governor is used, but on larger sizes a shaft governor is fitted, which

varies the point of cut-off. A ten horse-power engine, single cylinder, weighs about 600 pounds complete, while a ten horse-power compound weighs a little over 300 pounds. They can be run satisfactorily up to 1,000 revolutions, but generally are speeded at about 250. As the most important thing about an engine of this kind is the method of making the piston steam tight, it is here more fully described. The rectangular pieces, *C*, *Fig. 1*, fit snugly into the recesses prepared for them, and, as the steam is admitted on one side or the other, they are thrown against the opposite side and out against the cylinder by the steam pressure. The plates, *E*, are carefully finished along the inner edge and are set up from the outside. Steam is prevented from passing over the ends of the vanes or wings. At one end the piston head is fitted against the end of the cylinder and piston by scraping, and the plates, *E*, are recessed into the head. The other end of the cylinder is made of a plate, which is recessed for the ends of the plates, allowing a movement of the plate axially, and the piston and the plate present scraped surfaces to each other. This plate is set up by set screws on the outside. The tightness depends, therefore, on the accuracy of the surfaces originally and the care with which it is set up. Engines have been built varying from one and one-half to 100 horse-power, and have proved to be as tight as desired. The small floor space and head room required is not the least of the advantages of these engines. The connecting rods are quite ingenious and to me new. The brasses for each end are cast and fitted as shown in *Fig. 3*. The two ends are alike. *B B* are the brasses; *C C* are two rectangular plates fitting over the rods *A A*, which are smaller at *D* than at *A*, having a shoulder at *E*. The brasses and plates are held on by the nuts, as shown. The brasses are prevented from moving, as the rods *D* are recessed into the sides of the brasses. H. W. S.

ENGINEERING.

THE pontoon bridge over the Missouri River, at Nebraska City, is said to be the largest in the world. Its length across the navigable channel is 1,074 feet, while the back channel is traversed by a causeway 1,050 feet long, supported on cribs. The charter for this bridge has been held for twelve years, because of the difficulty of obtaining financial support for a project which appeared so impracticable. It is stated that the entire bridge was built in twenty-eight days, at a cost not exceeding $18,000, by Col. S. N. Stewart, of Philadelphia, assisted by General Lyman Banks, of Iowa.

The draw is **V**-shaped, with the apex down stream. It is operated by the current and controlled by one man. The clear span is 528 feet, the largest in the world. The bridge was completed in August and is doing good service. It will be removed during the ice season. H.

REMOVAL OF SMITH'S AND WINDMILL ISLANDS, PORT OF PHILADELPHIA.—The Committee on Commerce, of the United States Senate, have recommended the appropriation of $550,000 for the beginning of this work, of which $350,000 is to be available for the purchase of the lands, leaving $200,000 for procuring plant or for prosecution of work. The total estimate to complete,

as made by the Board of United States Engineers, is $3,500,000. At this rate it will require seventeen and one-half years, provided there be no failure of the bills during that period, and that the item be not scaled down. As yet there is no law nor provision requiring the riparian owners to extend their wharves to the proposed new line as the work progresses, and unless this is done, the work will prove a failure. H.

THE steel bridge on the Northern Pacific Railroad at the Missouri River crossing, between Bismarck and Mandan, is said to be in danger from a threatened landslide from the bluff on the left bank.

THE NICARAGUA CANAL.—Mr. A. G. Menocal, Engineer-in-Chief of the Nicaragua Canal Company, who is at present in New York, expressed himself in the following terms respecting the present status and prospects of this enterprise.

With the exception of some local work, the canal surveys are now about finished, and the perfected route as it now stands is at least twenty-five per cent. better than the one of 1885. The then estimated length of forty and three-tenths miles has been cut down to twenty-eight and eight-tenths miles, and the small surveys now going on are expected to reduce this to nearer twenty-eight miles. Everything is now waiting in readiness for the work of construction to begin, and on this trip Mr. Menocal is to interview the officers of the company to that end.

The people of Nicaragua and Costa Rica are awaiting the opening of the canal with the greatest interest, and confidently expect a wonderful development of the resources of their country when it becomes a settled fact. Mr. Menocal says that all the members of his staff have worked like beavers during the last season, with the exception of the physicians. They had absolutely nothing in their line to do, and to keep themselves from rusting from sheer inactivity, held chains for the surveyors, took barometrical observations and the like. The whole party slept in the open air every night, with no other protection than a canvas tent, and sometimes not even that; yet all were benefited rather than injured by the experience.

Mr. Menocal now has three divisions of engineers, eighteen in all, and a full complement of native laborers busily at work finishing up every detail of the surveys, and expects to have every inch of the route mapped out by the time he returns. There are no particular engineering difficulties to be surmounted in building the canal.

The heaviest part of the work is the making of a cut 119 feet deep through a two and three-quarter mile stretch of solid rock. About sixteen miles of the work will be dredged and the balance of nine miles is firm, low-lying ground that will only have to be dug to a depth of twenty feet. The canal is to be 120 feet wide, through the greater part of the distance, with sharply sloping sides that will not have to be walled up. Through the rock section it will be but eighty feet wide with nearly vertical sides. The whole canal will have an average depth of thirty feet, and will be able to accommodate the deepest draught vessels.

Once the work of construction is begun it can be carried on very rapidly, and the project will become a certainty in a very few years. The almost constant surveys since 1872 have made the engineers thoroughly familiar with every part of the ground and the chances of delays caused by unforeseen difficulties are reduced to a minimum. Mr. Menocal expects to see President Cheney and his colleagues very shortly, and get his orders to return and actively begin the working out of one of the greatest projects of the age.

W.

THE PANAMA CANAL.—The *Engineering News* has lately published an article on the actual status of the Panama Canal, giving the results of a recent expert examination of the entire length of the canal, and accompanied by a progress profile, showing the amount of work done and undone to January 1st of the present year, both for the sea-level and lock canal. The profile shows that the only work which is anywhere near completion, is about eleven miles of dredging on the Atlantic end and about a mile at the Pacific end. On the remainder of the work the proportion done is very small in comparison with that undone. The estimate given in connection with this profile shows a total of 34,081,000 cubic metres remaining, without allowing for the changes of river channels, Gamboa dam, etc., which raises the aggregate to 51,000,000 cubic metres. The company had admitted 32,000,000 to 40,000,000 metres.

At the highest rate yet reached of 1,000,000 cubic metres per month, it is estimated that at least four years will be necessary to finish the canal, if there is no lack of money.

The total amount of cash actually expended up to the present date is $177,910,000, represented by $351,150,900 of securities.

The amount necessary to be raised to complete the canal is estimated by the *Engineering News* at a minimum of $230,000,000, which would be represented by at least $500,000,000 of new securities.

The article declares that the progress profile makes it evident that not one-tenth of the work, nor one-twentieth of the money has yet been spent, which would be required to open a sea-level canal, which Lesseps declared last November would be opened February 3, 1890. Therefore, we can only escape from the conclusion that the impossibility of completing a sea-level canal has been known for three or four years at least by assuming colossal ignorance, either of which is equally fatal to their creditability in regard to the lock project. The worst feature of the progress profile to those familiar with the proper conduct of public works, is not so much the small aggregate of work done, but the distribution of it, in the damning evidence it bears that all has been done for theatrical effect, to facilitate "raising the wind" by producing an impression in the ignorant and unthinking, rather than to so conduct the work as to complete it in the least time at the least cost. The worst feature of all is the completed section on the marshes, which should not have been touched at all until the heavy work was nearly done. The next worst, is doing so much work where it is likely to be washed out by floods in the Chagres River, without completing the costly and doubtful damming and diversions of that river which are hardly yet begun.

W.

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Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, September 19, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, September 19, 1888.

Mr. JOS. M. WILSON, President, in the Chair.

Present, 249 members and thirty-nine visitors.

Additions to membership since previous report, seven.

The Secretary reported the declination of Mr. THEO. C. SEARCH, who had been elected to the Board of Managers to fill the unexpired term of WILLIAM HELME, deceased. Mr. JOHN LUCAS was elected to fill the vacancy.

Mr. HENRY PEMBERTON, JR., read a paper entitled "An Inquiry into the Relative Value of Aluminium and its Alloys in the Arts." The paper appears elsewhere in this impression of the JOURNAL. Mr. W. E. GUMP, of New York, read a paper descriptive of the system of the Writing Telegraph Company, embracing the Cowper-Robertson system of autographic or *facsimile* telegraphy. The subject was illustrated by the exhibition of the system in actual operation. The paper appears elsewhere in this issue of the JOURNAL.

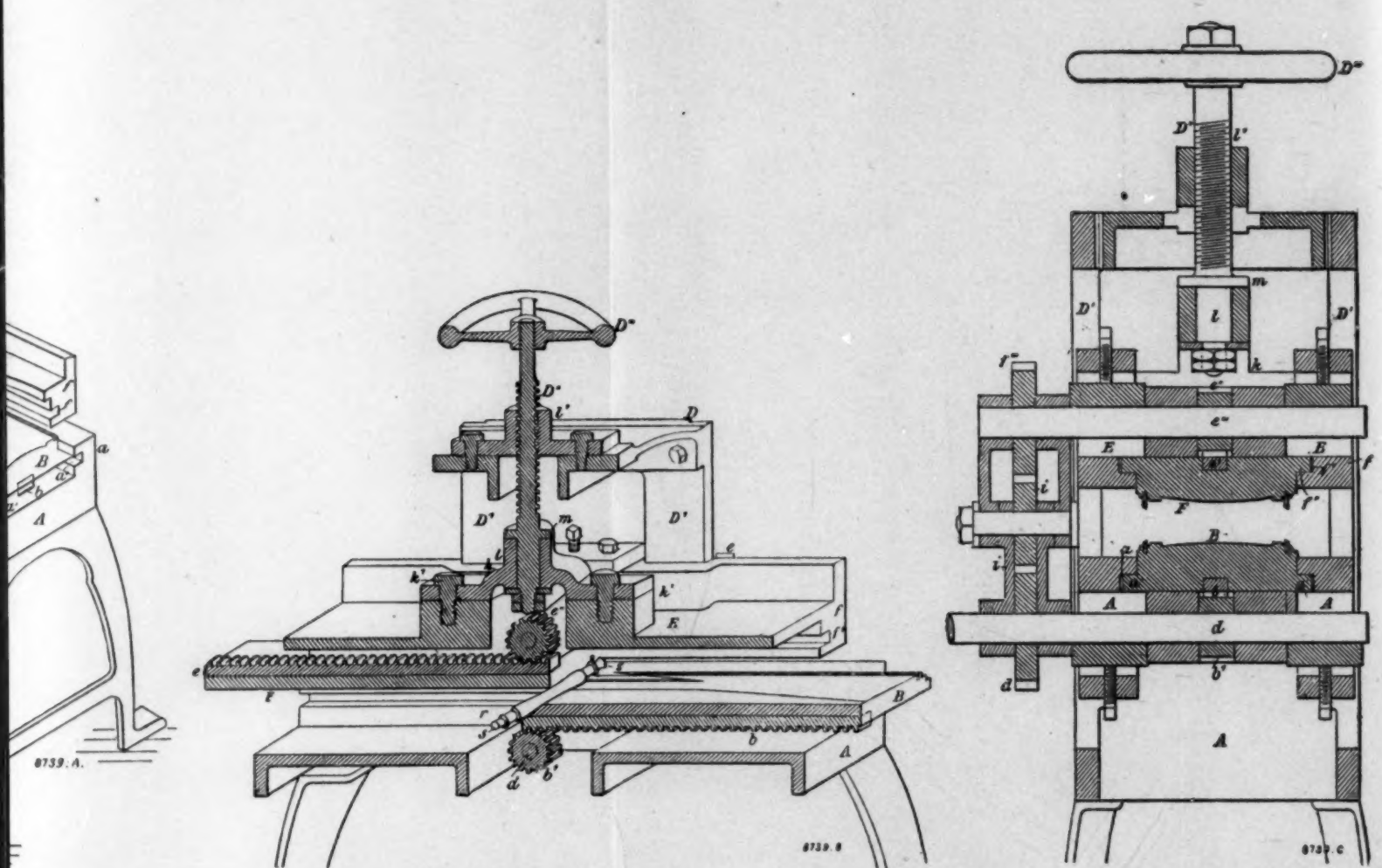
Prof. ELIHU THOMSON, of Lynn, Mass., gave an oral account of the system of electric welding which he had invented, with especial reference to the machines and appliances that had been devised for carrying the process into operation. He illustrated his remarks by a practical demonstration of the operation of electric welding. An abstract of Prof. THOMSON'S remarks has been prepared for publication.

The subject of the Cowper-Robertson writing telegraph was referred to the Committee on Science and the Arts for investigation.

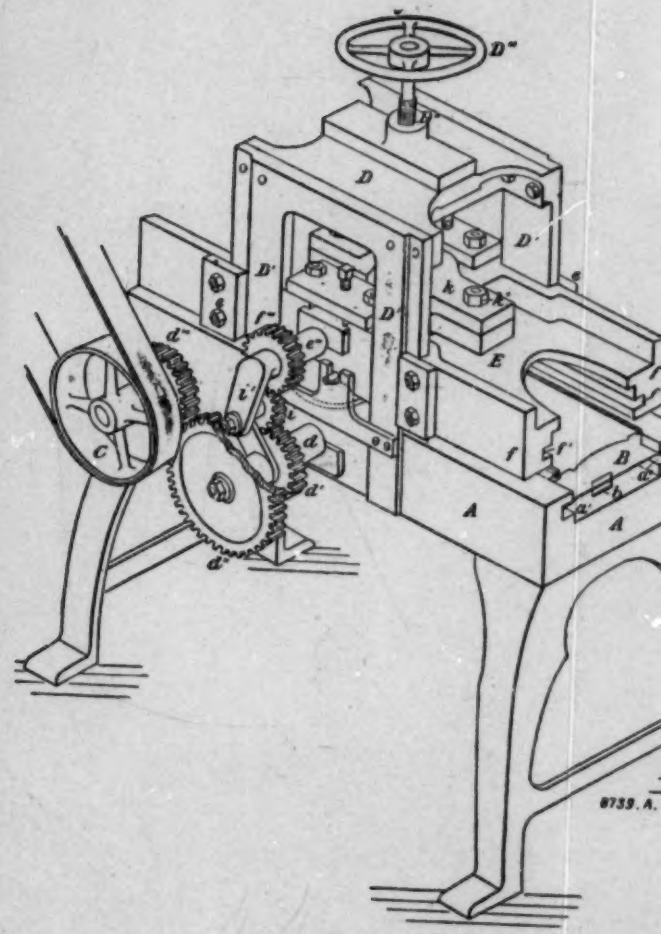
A communication by Mr. W. E. LOCKWOOD, on the subject of the Hammer-Blow of Locomotive Driving Wheels, was referred to the same committee, with power to act.

Adjourned.

WM. H. WAHL, *Secretary.*



SIMONDS'S UNIVERSAL METAL ROLLING MACHINE (Simonds' U. S. Patent No. 319,752).



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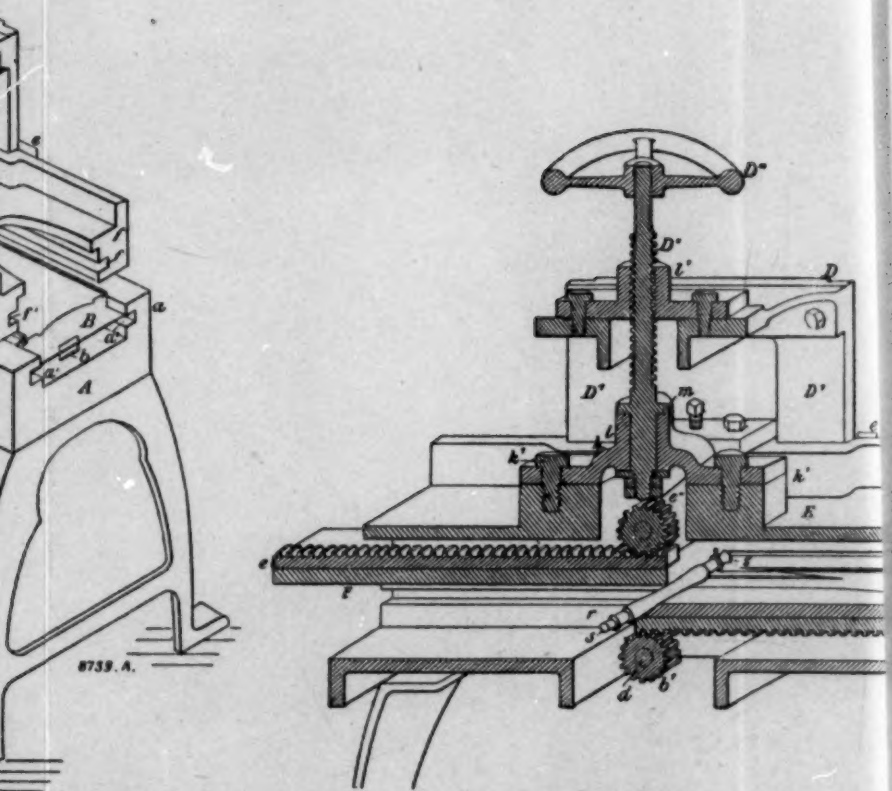

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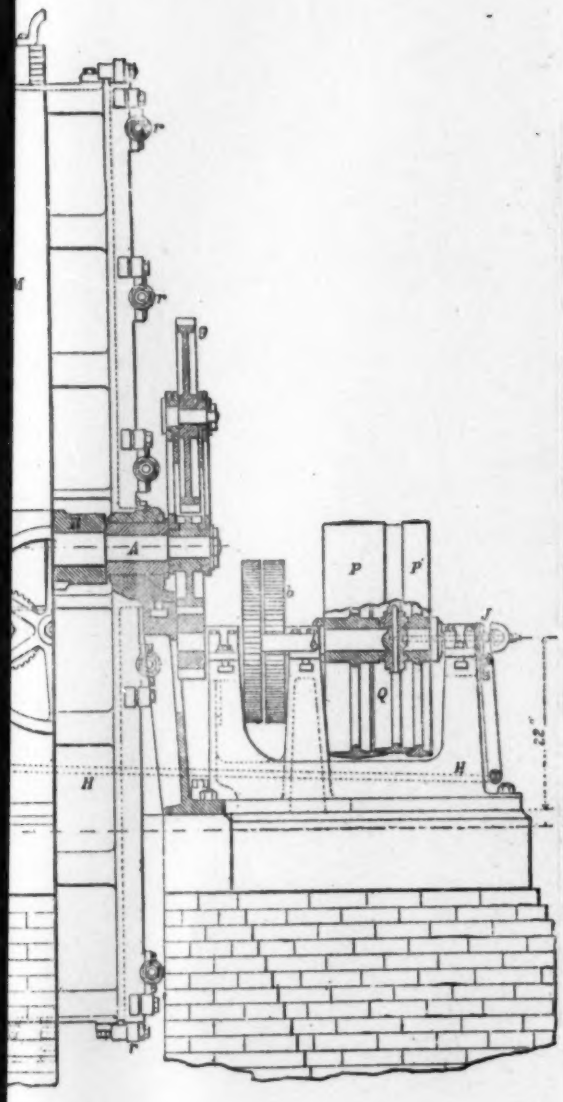

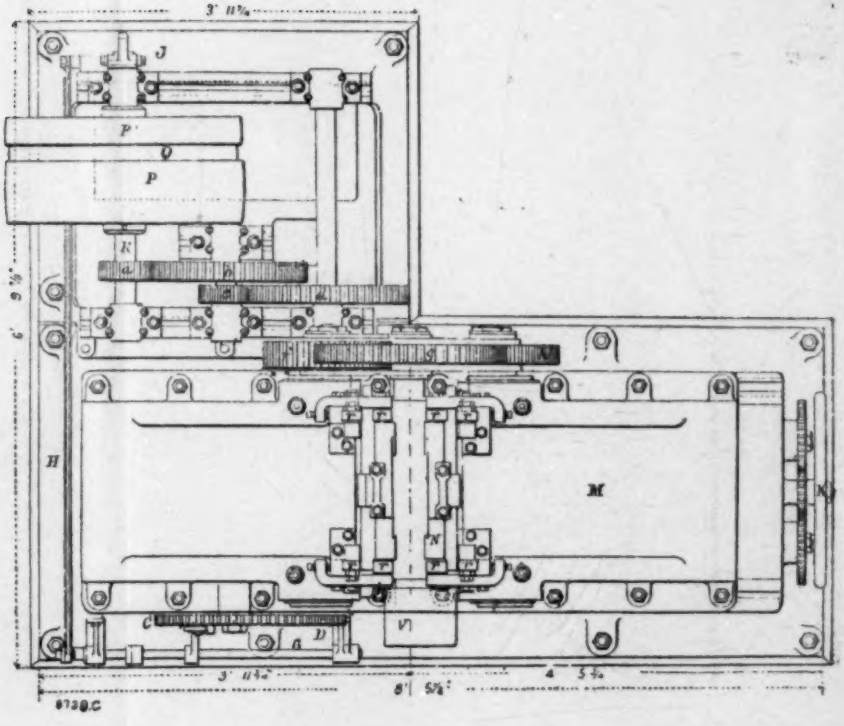

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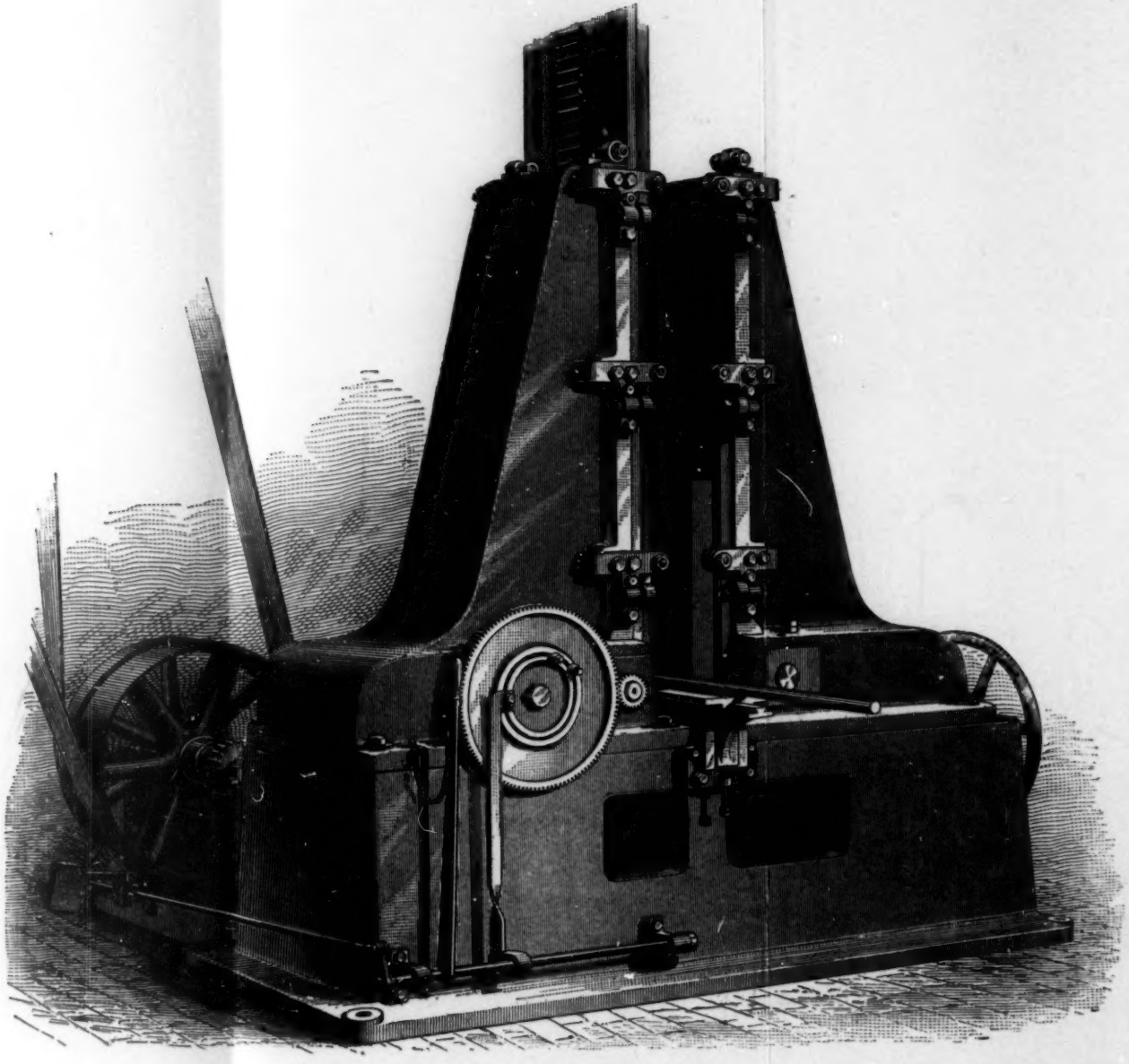
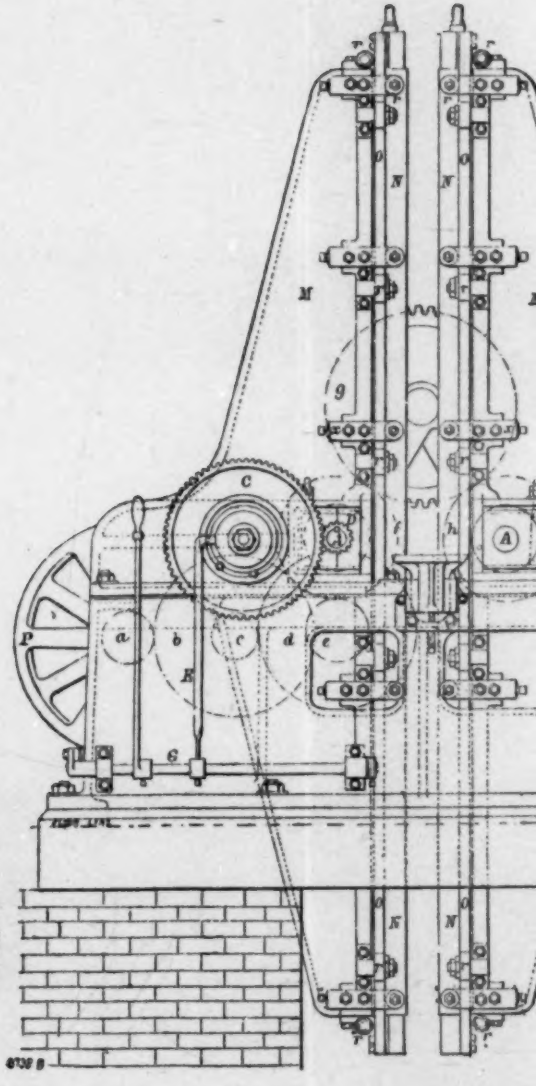
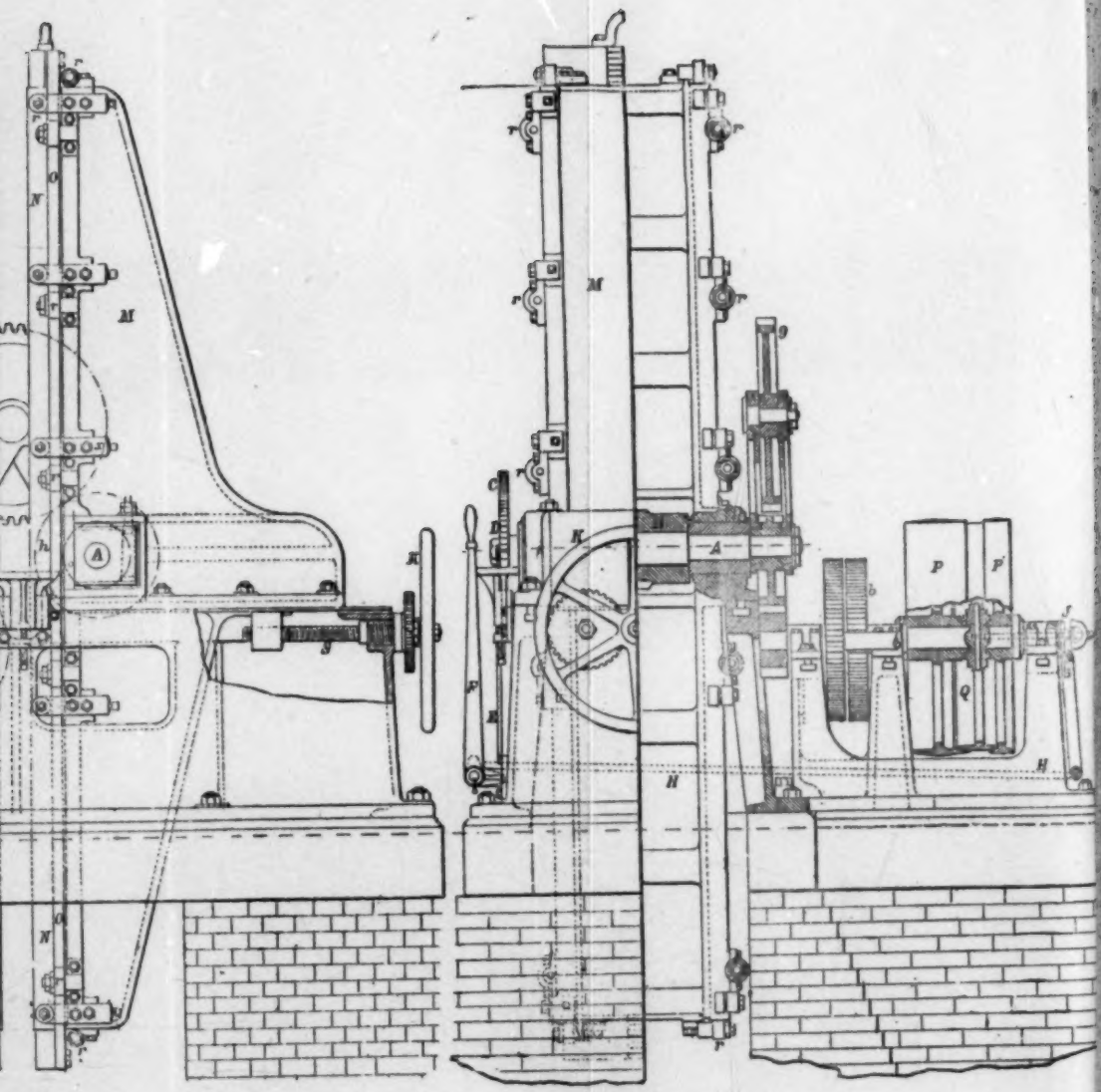




SIMONDS'S UNIVERSAL METAL ROLLING



L ROLLING MACHINE (Perspective View, Vertical Sections and Plan).